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Feb. 25, 1918.

MILITARY BRIDGES:

WITH

SUGGESTIONS OF NEW EXPEDIENTS AND CONSTRUCTIONS
FOR CROSSING STREAMS AND CHASMS.

INCLUDING, ALSO,

DESIGNS FOR TRESTLE AND TRUSS BRIDGES

FOR

MILITARY RAILROADS.

ADAPTED ESPECIALLY TO THE WANTS OF THE SERVICE IN THE
UNITED STATES.

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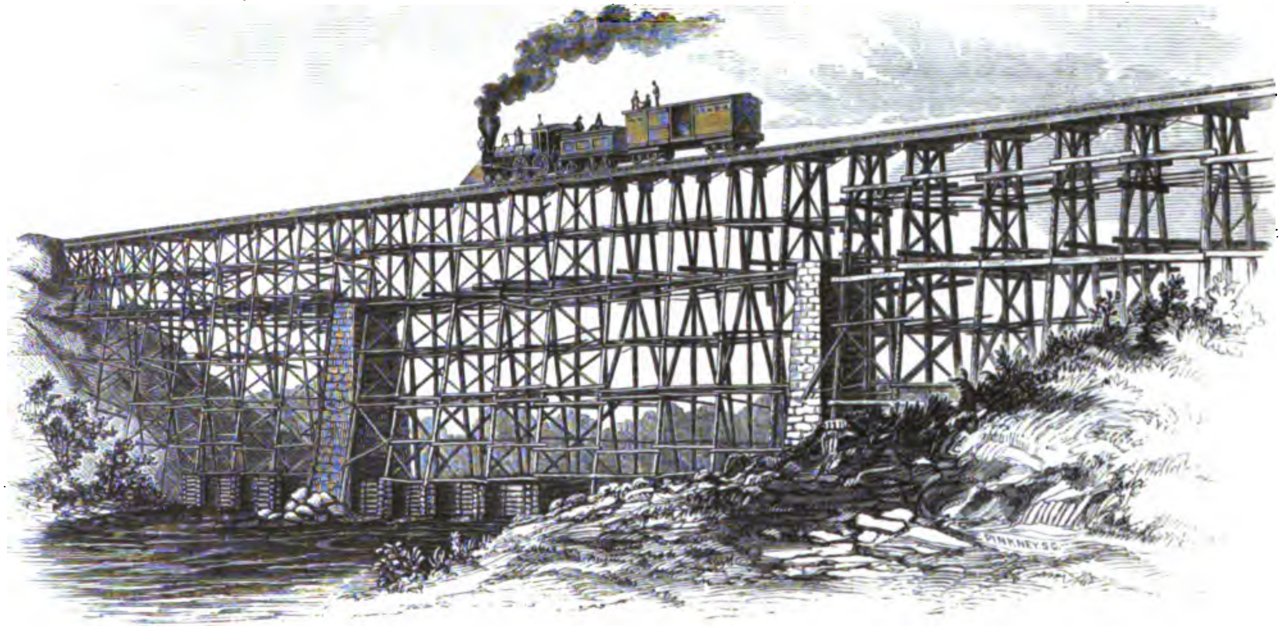
BRIDGE CONSTRUCTION," ETC.

Illustrated by Sixty-nine Lithographic Engravings.

NEW YORK:
D. VAN NOSTRAND, 192 BROADWAY.
1864.



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MILITARY BRIDGES.

INTRODUCTION.

The experience and observation of the author during a period of nearly two years, in which he was connected with the military service, have convinced him that the elaborate works of Sir Howard Douglass and others do not describe expedients and modes of construction that are adapted to the local and other peculiarities of the United States service. The plans which they describe are generally too complicated, and require material not readily accessible, transportation not easily procurable, and skill not always at command.

In none of the works previously published can be found plans for *military railroad bridges;* and as the present civil war in the United States involves transportation by rail to an extent never before known—as the varying fortunes of war require bridges to be destroyed and reconstructed at short intervals, and in the most expeditious manner possible—it becomes important that officers, intrusted with duties either of destruction or reconstruction, should know what are the safest and best plans, and how to use advantageously the resources that may be available.

European armies have relied chiefly upon wagon transportation over common roads. In cases of retreat, the pursuers and the pursued were much more nearly on an

equality than when the mode of transportation is by rail. Of course, the retreating army would destroy bridges, to retard pursuit; but the communications could in general be soon restored by fords, pontoon trains, or other expedients. It is widely different when a retreating army sends its baggage and stores by rail, and marches after them without encumbrances, while the advance of the opposing forces is retarded by the necessity of reconstructing bridges of sufficient strength to carry railway trains, and often of procuring iron to relay tracks. The disparity of advantages between the advance and retreat is greatly enhanced, when the pursuers are increasing the distance between themselves and their base of supplies, with the constantly increasing danger of having bridges destroyed and communications broken in their rear, while the pursued are reducing the distance of transportation, both for re-enforcements and supplies. The one retires rapidly on a line of road in good condition; the other advances slowly on a broken line, which must be reconstructed. It is not surprising, therefore, that the history of the present war scarcely affords an instance of the successful pursuit of a retreating enemy, but, on the contrary, of many signal failures. It could scarcely be otherwise, excepting where railroads did not exist, and both armies were equally encumbered, or equally unencumbered, by transportation.

No one who has been familiar with business transactions, conducted with the efficiency and system which usually characterize the operations of individuals, can fail to experience emotions of pain and regret at the enormous expenditure for transportation, in proportion

to the results derived from it. In the armies of the United States there have been, at times, nearly half as many animals as men, exclusive of cattle; each animal requiring an amount of boat, rail, and wagon transportation equivalent to five men; and, so far from conducing to efficiency and mobility, the enormous baggage-trains have served to encumber roads, and often render movements impossible. If the practical suggestions of General McDowell could be adopted; if soldiers upon marches would carry bread, coffee, and salt, and depend for meat upon cattle driven on the hoof; if, in addition thereto, a thoroughly drilled engineer brigade, with officers capable of devising expedients, could cross armies over streams, by the use of such materials as the country afforded, without being so entirely dependent as they have been upon bridge-trains, the number of animals could probably be reduced one-half, and the whole transportation of men and animals almost to one-third, of that which is now considered necessary.

While the author claims that a large portion of the material in this work is new, yet the desire to receive credit for originality has not deterred him from using any thing of practical value to be found in the writings of others. He has, accordingly, consulted and made extracts from Sir Howard Douglass, Haillot, Meurdra, General Cullum, General Meigs, Captain Duane, and the "Aide Mémoire;" the object being to make a practically useful book, adapted to the service of the armies of the United States, and suggesting expedients, with a view to make available materials everywhere at command, but heretofore neglected, and to reduce expenses, which are exhausting the resources of the country.

BRIDGES FOR MILITARY RAILROADS.

BRIDGES on military railroads are not required to fulfil precisely the same conditions as those which are, or should be, constructed for general railroad business.

On ordinary roads, permanency, with a minimum expenditure for repairs, constitutes, perhaps, the requisite which stockholders and capitalists would consider most desirable; while, for military purposes, time of construction and simplicity of detail are far more important than durability.

It is desirable, also, that a bridge, to be constructed with the rapidity required, and under the conditions which usually exist during an active campaign, should not demand a very high degree of mechanical skill in its constructors. Its parts should be few and simple; the pieces which occupy corresponding positions should be precisely similar, so that any one, taken up at random, would be sure to fit. The plan should be such as to accommodate itself to any length of span, so that material for any extent of bridging could be prepared in advance, and would answer for any span or for any locality.

When the structure is not liable to be carried away by freshets, the elevation not too great, and material within reach, an ordinary trestle-bridge is preferable to any other; one of its great advantages being, that the

material is usually procurable in the vicinity of the proposed structure, and its transportation by rail avoided.

In the construction of such bridges, round sticks cut from the forest are quite as good as the best sawed timber, but ordinary bridge-builders and carpenters will not use them, if they can avoid it.

Military Railroad Trestle-Bridges.

Where the height does not exceed 25 or 30 feet, the trestles should be made in the form of the letter W inverted, by which the necessity for braces will be avoided. Straight sticks, 9 inches in diameter at the top, will be sufficient for legs. To give lateral stiffness, poles, 5 or 6 inches in diameter, should be spiked longitudinally and transversely to the trestles, when in position, as shown in the plan. (Pl. I.; Fig. 1; upper portion.)

The sills should be flatted on two sides. The caps should square, not less than 10 inches, and should be connected with the legs by treenails 2 inches in diameter.

It is best to make the caps 16 feet long, so that the bridge can be planked over and used for artillery or infantry. In this case, no cross-ties are required. The rails can be spiked directly upon the transverse planking. (See Fig. 1; Pl. I.)

When the height is too great for single trestles, they must be erected in two or more tiers. In this case, the form represented in figure 2 is recommended. In framing this bridge, it is proper that all the inequalities of surface should be compensated for in the first series, so

that the caps, when in position, will be in a straight line. By observing this precaution, all the trestles of the remaining series can be made of precisely similar dimensions in each, which will greatly expedite the work.

Framing the Trestles.

A platform on which to frame the lower trestle consists simply of three parallel logs, about 10 feet apart. The upper log should be squared, and so placed, that one of the flat sides will indicate the position of the top line of the legs. The position of each leg should be distinctly marked upon the three logs, so that, when the legs are laid across the marks, they will be in their true relative positions.

Spike a 3-inch plank across the legs, the edge of which will be in the same vertical plane with the face of the top log; saw off the legs even with this plank; spike another plank across the middle of the legs; a third, in such a position that its lower edges will give the line of the bottom, as determined by measurement and level; saw off the bottom of the legs which project beyond the plank; pin a fourth plank across the top ends for a cap, allowing the treenails to project 3 inches, and well tapered on top ends; another plank at the bottom for a sill, and the trestle is ready for raising.

The plank at top of the lower trestle answers very well as a cap at all times, but in some localities, where the bottom is unequally compressible, it will be necessary to use heavy sills; in this case, the posts and sills must be bored for dowels with the same measure, so

that the dowels will fit well, and enter readily. If no mistake has been made in getting the height of the lower trestles, the upper series will be all alike, and no difficulty will be presented in framing them. Plank caps can be used, except for the top series, where square or flatted timbers should be employed. In all cases, 2-inch dowels are used instead of mortises and tenons.

Neither bolts nor braces are required in any part of the structure, excepting that in high trestles plank or poles, spiked as lateral longitudinal bracing between the caps, is an advantage, and the longitudinal poles or ties at the ends of the bridge should be butted against masonry, or dowelled into logs that have been bedded in the bank. The object of these arrangements is to resist motion in a longitudinal direction, and stiffen the posts; the transverse motion being resisted by the shape of the trestles themselves.

Raising the Trestles.

The trestles having been framed, and placed in convenient positions on the ground, or floated on the water, they are raised to the place which they are to occupy by means of blocks attached to sliding-beams. These sliding-beams consist of long timbers, 35 to 40 feet in length, and about 12 inches square, in cross section. They are trussed with ropes, rods, or chains, as represented in Pl. I., figure 3, and on an enlarged scale in Pl. II., so as to give them sufficient strength to hold the heaviest trestle, and are projected forward a distance equal to one interval. Large iron pulleys are placed in the ends, over which pass the ropes required in hoisting. The power employed is usually that of a large number

of men, forming lines on each side of each rope, so as to raise or lower, by signal, either side of the trestle at pleasure. The inside ends of the sliding-beams are tied down, to keep them from tilting.

The sliding-beams may be made very conveniently of planks bolted together. Pl. II. represents an isometrical perspective of the sliding-beams on a larger scale.

The organization for framing and raising a trestle-bridge can best be illustrated by reference to a case of actual construction. It will be understood, of course, that no invariable rules can be prescribed for such operations, but the details must vary according to circumstances.

The illustration given is that of a trestle-bridge built across Potomac Creek, on the line of the Richmond, Fredericksburg, and Potomac Railroad. The height was so great as to require three series of trestles. The timber used was chiefly round sticks, cut in the woods; hauled a mile and a half with oxen, then loaded on a truck; hauled a mile farther on a railroad; thrown off the end of an embankment, framed near the level of the stream, and then elevated by the sliding-beams, and placed in position. The laborers and mechanics were chiefly soldiers, detailed from volunteer regiments, with civilians as foremen. Some time was required to effect an organization, but when this was accomplished the work advanced rapidly. It is all-important, that, when squads are formed and become familiar with their duties, there should be no changes of details until the work is finished. To substitute new and inexperienced men for those who have become familiar with the work, renders satisfactory progress impossible. For this rea-

son, it is desirable that a construction corps should have about its organization some of the elements of permanency; if nothing more, there should be small squads of four or five experienced men, to which others could be added by temporary detail, whenever active operations required such increase.

Organization for the Construction of the Potomac Creek Viaduct.

ORGANIZATION AND DUTIES OF SQUADS.

Squad No. 1, on top of bridge, to move out sliding-beams, and put on ties, required	10 men.
Squad No. 2, to attend to top of second trestle, and bottom of third, required	5 men.
Squad No. 3, to put trestles together, put lower legs in sills, and heels of second series in places, required	8 men.
Squad No. 4, to attend to framing and carrying timber on bank	10 men.
Squad No. 5, to frame timber, and put sills on cribs	30 men.
Squad No. 6, to run in timber at grade, and, with assistance of others, to haul on ropes	12 men.
Squad No. 7, to put timber down bank, and haul on ropes	12 men.
On the south side all will be duplicated except	
Squad No. 5, requiring	57 men.
And the numbers of the squads should be continuous, which will extend the numbers to 13.	
Squad No. 14, for cutting timber in woods	20 axemen.
Squad No. 15, for loading trucks	20 men.
Squad No. 16, to assist in clearing roads and loading logs in woods	12 men.
Squad No. 17, drivers of ox teams	10 men.
Total force at work,	219 men.

If eighty men be allowed for sick, for guards, and other purposes, the proper allowance should be, at least, three hundred men.

Transportation.

If the bridge is to be built entirely of round logs, hauled half a mile in the woods, and transported on railroad one mile, twenty yoke of oxen, one pair of mules, and one car, would be required at each end of the bridge, to vary according to circumstances.

One pair of mules extra should be provided, with wagon and driver.

Total yokes of oxen (with two experienced herdsmen)	40
Pairs of mules	3

Tools, Implements, etc.

Axes	50
Shovels	20
Broad Axes	20
Picks	12
Handsaws	25
Cross-cut Saws	20

Ropes, etc.

4 of 500 feet in length, 1$\frac{1}{4}$ inch diameter, 8-inch pulleys.
4 small tackles, 4-inch pulleys.
8 pulleys, 8 inches diameter, 1$\frac{3}{8}$ fall.
50 kegs of boat spikes, $\frac{3}{8}$ inches square, 7 inches long.
10 kegs of nails, eight and ten penny.
11 spike mauls.
20 chains, 6 feet long, hook and ring made of $\frac{1}{2}$ inch diameter round iron.
40 ox-chains.

Lines and Rods for Sliding-Beams.

20 log chains.
2 dozen files for saws.
6 wooden mauls.
1 barrel of oil.
24 bolts, 10 to 11 inches, $\frac{7}{8}$-inch round iron; 24 bits, of 24 inches.

Regulations.

Each officer in charge of a squad should keep time, and be responsible for tools.

Each tool should be numbered, and a record made of the number of the tool furnished to each individual.

A bugle should be blown, by direction of the officer of the day, at the sound of which squads should fall in and march promptly to the place of rendezvous.

The officer of the day calls out the name of the officer in command of Squad No. 1, who will order his men to step forward.

The officer of the day will see if the detail is full; if not, who is absent.

The squad will then face about, and march to work.

No. 2 will then be called out in the same manner, until all have been disposed of.

This has been found, in practice, to be the quickest way of getting men at work, and involves least confusion.

The officer of the day will go around constantly, and see if men are present and attending to duty. If he has reason to believe that any of the men have deserted any squad, he will direct the officer in charge of squad to assemble his men, call the roll, and note absentees, who will be reported at head-quarters. All who are late, who do not perform duty properly, or who quit before the sound of the bugle, should, in like manner, be reported, and a record made of all such reports.

The detachment for construction should be well officered, with efficient squad-masters. The pay should be by the hour, to be diminished or withheld at the option of the officer in command.

The squad-master should return the number of hours made by each man as mechanic or laborer to the officer of the day, and the officer of the day should return the whole to the book-keeper, to be entered in a suitable book prepared for that purpose.

The columns should be extended entirely across both pages, and headed as follows: Names of men: thirty-one columns for days of the month in which to enter the hours worked of each day: Total hours: Price per hour: Total amount: Remarks, etc.

The tool-book should contain a record of the names of men, a description of the tools furnished, the date when furnished, and the numbers marked on the tool.

Each squad-master should be furnished with a small memorandum-book, with the description and numbers of tools furnished to members of his squad.

The squad-master should report to the officer of the day whether the tools have all been returned in good condition; and if not, why not.

Individuals who lose or wantonly injure tools should be required to submit to a reduction of extra pay until they are paid for.

Separate tool-boxes should be provided for the tools of each squad, numbered with the number of the squad, and the key kept by the squad-master. A second key should be kept by the person having general charge of tools. The keys for no two boxes should be alike; they should be numbered to correspond with the boxes, and the boxes placed under guard.

The commissary department should be properly organized, so that no delay can possibly occur from want of rations. Suitable cooking utensils should be pro-

vided, and the men detailed for duty at daylight should not be required to cook their own breakfasts before going out. Breakfast should be prepared for them, either by colored cooks, or by details for that purpose of men not required for other duty. If permanent cooks could be employed, and the men mess in common, it would be a great improvement. Those who work all day in the woods, in lumbering, should take dinners with them.

Feed should always be taken for the oxen, as much time is lost in driving them to a distance to feed. If the force is designed to operate at points with which there is not continuous railroad communication, wagons for transportation of tools will be required.

These practical suggestions are the result of experience. Those who attempt to do work with details of troops unaccustomed to mechanical operations, particularly if such details are daily changed, will find that the most difficult task is organization; and that, without it, confusion will reign supreme and progress be impossible. It will be discovered that, without individual responsibility, tools will be abused, thrown away, or lost, and that the instructions given must apply to the most minute details, or they will be neglected—a consequence which results, in general, more from want of skill than want of disposition.

Military Truss-Bridges.

A truss for a bridge adapted to military purposes must be simple. The arrangement of the parts must be such that soldiers unskilled in mechanical work can understand the combination and put the work together.

It must be composed of parts, such that all the pieces of the same class—chords, ties, or braces—will be identical, and any one taken promiscuously from a pile will work in, without fitting or trimming.

It should be such as will admit of the employment of a very large force, so that all parts of the bridge may be progressing at the same time.

It should be such, that bridges to any extent could be prepared in advance, without regard to locality or span, and would be sure to fit, without alteration, when on the ground.

The simplest possible combination to support a constant load is an arch with a tie; and the kind of arch most readily constructed is one of plank or boards.

For a variable load, an arch counterbraced or connected with a truss, capable of resisting a change of figure, is the simplest possible arrangement.

The truss which is most easily framed and most readily put together, with unskilled labor, is a lattice, or some modification thereof.

These considerations have led to the adoption of the form of truss which will now be described. (Pl. III.) The strength or power to support a load is given by an arch, with a tie-beam connecting the ends. A plank truss protects the arch from change of figure by the action of variable loads. (See Pl. III.)

The minimum height of truss for all spans, where the track is upon the lower chord, should be such as will clear the smoke-stack of an engine, say sixteen feet above the rails; and, for the sake of uniformity, the same height of truss should be preserved where the track is upon the upper chord.

Chords.—(Details, Pl. VI.)

The chords are composed of planks 3 inches by 12, and 32 feet in length. The lower chord will be composed of 4 to 6 such pieces on each side of each truss, making 8 to 12 lines of lower chord plank on the two sides; the joints break at intervals of 4 feet.

Wooden pins, or treenails, pass through the chords at intervals of 4 feet. (Plate VI., Fig 1.)

Instead of using three or four small pins at the intersections, as in the ordinary lattice, the suggestion of Henry R. Campbell, Esq., civil engineer, has been adopted, and one large pin substituted. A single pin, with a given resisting area, will cut away less of the chord than a number of smaller ones. These pins will be 3 inches in diameter.

The holes in the chord-plank should be bored by machinery, which can be so arranged as to bore all the holes at once; but, if bored by hand, great care must be exercised that the distances are accurately measured with a pattern, and the bits truly centred. Whether turned upside down, or end for end, every piece must fit; hence the utility of using but one row of holes, which can be bored accurately along the middle line of the stick. The chord-plank being 32 feet long, and the holes 4 feet apart from centre to centre, there will be half holes at the end of each plank, so that, when any two are butted end to end, a complete circle will be formed, through which the pins will pass. (See Plate VI.)

Half way between the pins, the chords are bolted with $\frac{7}{8}$-inch bolts. The holes for these bolts can also be bored in advance, and the measurement, if

made from the middle line of the timber, by means of an accurate pattern, should be sufficiently on a line to avoid all difficulty in passing the bolts through. To accommodate any slight variation, the holes can be bored an inch or an inch and an eighth in diameter.

The nuts on the chord-bolts will be on the inside of the chord, but there will be no difficulty in turning them.

After the chords are tightly bolted together, holes of an inch and a quarter in diameter are bored vertically, on each side of the bolt, and about 6 inches apart along the joints, into which pins of hard wood, thoroughly dried, are driven. These pins act as keys, to prevent the chord-planks from slipping upon each other.

Blocks, 6 by 12 inches, and 18 inches long, bored with 3-inch holes, are placed between the chords to separate them where they are not kept apart by the intersection of the braces.

It will be readily perceived that the operation of boring the holes and driving the pins, for keying the chords, can be carried on without interfering with any other work upon the bridge. The holes must be bored truly, in the vertical planes of the chord joints; but may be inclined in these planes without detriment.

At the extreme ends of the chords, at both of the abutments, the half holes would not hold pins to secure the intersection of the braces. A bolt must therefore be substituted. No disadvantage will result from this fact, as the truss is always extended back at least 8 feet from the face of the abutment.

Upper Chords.

The upper chords are precisely similar to the lower ones, and are bored in the same way, except that there may be only half the number; and in single spans there is no absolute necessity for the vertical holes and vertical pins to prevent slipping. The long bolts for the lateral bracing pass entirely through the chords from side to side.

Truss Plank.

The vertical and inclined planks which constitute the sides of the truss are all cut to a pattern and bored, each with holes 3 inches in diameter. The ends of the inclined planks can be left square; no advantage is gained by cutting them to a bevel. These planks are all 2 inches thick and 10 inches wide.

Arches.

The arches are essential parts of the truss, and are mainly relied upon to sustain the load. They are constructed of inch boards, sprung into position, and securely nailed to each other. The depth of each arch will be about 18 inches.* One arch is placed on each side of each truss, from which the floor and track are suspended by means of rods. (Fig 2.)

* Experience has shown that the most convenient way in which the arch can be constructed, consists in placing three continuous layers of boards around the circumference, flat sides uppermost, and breaking joint; these boards to be well nailed. Next, twelve layers of boards, placed vertically or edge upward, forming as many polygons; or an equivalent thickness of plank may be used. All these boards should be well nailed and spiked; lastly, other boards are placed on top to cover and give a neat finish.

Skew-Backs.

The arch rests on the top of the lower chord, and the chord on a wall-plate; from the heel of the arch to the end of the chord, a distance of 8 feet, extends a skew-back piece, which is bolted by vertical, or, still better, by inclined bolts, to the chords, and to a corbel below the chord.

At intervals of 9 inches, a pair of 1-inch vertical bolts is passed through the chords and skew-back; and between the bolts, keys of hard wood or iron are inserted; a 3-inch hole may be bored horizontally, and pieces of 3-inch pipe driven in, which will take the place of keys. (Plate VI.)

Stirrup-Blocks.

Stirrup-blocks are suspended from the arch by means of the suspension-rods. In bridges that are not oblique, it may be convenient to extend them entirely across, and spike the lower horizontal braces upon their upper surfaces; but the ordinary Howe bracing is preferable.

Framing.

The auger and the saw are the only tools required in framing the truss. If the chord and lattice planks are cut to the proper lengths, and the holes accurately bored, there will be no difficulty in putting the bridge together; all this work can be done in advance, before the materials are brought upon the ground, and the operation of raising can commence as soon as the false-work, or scaffold, is prepared.

Raising.

The first operation in raising will consist in laying the lower chords; the eight chord-planks, commencing at one

end, should be laid in the following order, as to lengths: 4, 32, 8, 28, 12, 24, 16, 20. After these pieces are laid, so as to break joints properly, all the rest of the chord-planks will be in lengths of 32 feet, and the joints will be at intervals of 4 feet.

When the squads engaged in laying the inside chord-planks have advanced about two lengths, another squad can put in the 18-inch blocks, and drive the pins through the blocks and chords.

Others can at the same time put in place, and screw up tightly, the chord-bolts. Several other squads can commence boring for the vertical pins in the chords, after the chord-bolts have been tightly screwed. Others drive the vertical chord-pins, and set up the lattice-truss planks. The three planks which intersect at any point on the bottom chord should be laid together, the vertical plank being in the middle. Each set of three planks should be held in place by nailing on them two pieces of 2-inch plank, 6 by 10 inches, which will afterwards be used as blocks between the braces at the intersections where there is no vertical plank. They can be put together in sets in this way by a separate squad, and raised all together in a vertical position. The long 30-inch pin can then be driven. When several sets have been placed in position, all the planks standing vertically, the brace-planks can then be moved right and left in position, and pinned at the middle intersection.

When several sets of the lattice-plank have been placed in position, and pinned at the middle intersections, the top chords can be put on. To do this, a temporary scaffold can be formed, by nailing boards across the vertical plank at a proper height, or by means of a

traveller, as shown in Plate V. It will be difficult to put the upper chord in position if the false-works have settled out of line; but to correct this, it is only necessary to sight along the lower chord, and drive in wedges where it is found to be too low. When the lower chord is straight, the upper one can be pinned without difficulty, and when pinned it becomes self-sustaining.

After the top chords have been pinned, other squads can follow with the lateral bracing floor-beams and track. The last operation will consist in plumbing the trusses, and spiking on braces to keep them in position.

It will be perceived that, when the lower chords are laid, men can be set at work along the whole extent of the bridge, in bolting and pinning the chords, setting the lattice-plank in position, placing floor-beams, and putting in lateral bracings. The chords and tracks are the only portions that should be laid continuously from one end; but even this is not absolutely necessary. A single line of lower chord-plank laid down continuously will indicate the positions of all the pieces of the structure, so that, with very little care and calculation, operations can progress on every span of a long bridge at the same time.

Befóre laying the chord-plank the position of the inside layers should be marked, by nailing a short piece of board, six inches wide, vertically on each of the caps of the false-work. The inside planks will be laid against these boards and butted against each other. Other gangs will follow with the outside plank. No fitting or trimming being required, the work can progress with astonishing rapidity. After the false-works have been erected and the material distributed, a thousand feet a day, with a properly organized and sufficiently numerous

corps, would not appear to be impossible—a rapidity of construction approximating to which has never yet been attained, and is probably unattainable on any other plan.

If the locality is such as to require the track to be upon the upper instead of the lower chords, the only change required will be the substitution of posts on top of the arch, instead of the suspension-rods; and diagonal braces, from the top to the bottom chords, instead of knee braces.

BILL OF TIMBER FOR 1000 FEET OF MILITARY RAILROAD BRIDGE.

Names of Pieces.	No. of Pieces.	Length in feet.	Size in inches.	Kind of Timber.	No. of feet, Board Measure.	
Wall Plates	28	21	8 × 12	White Oak	4,704	
Bolsters	56	23	12 × 12	"	15,456	
Arch Abutment	56	8	12 × 12	"	5,376	
Arch Blocks	480	2½	6 × 6	"	3,600	
Pins	500	2¾	3 × 3	"	1,032	
"	500	1¾	3 × 3	"	656	
"	250	¾	3 × 3	"	140	
				Total White Oak	30,965	30,965
Chords	750	33	3 × 12	White Pine	74,250	
Posts	250	21	2 × 10	"	8,750	
Braces	500	28	2 × 10	"	23,333	
Laterals	168	19	5 × 6	"	7,980	
"	168	20	5 × 6	"	8,400	
Floor Beams	500	19	7 × 12	"	66,500	
Track Stringers	125	32	5 × 10	"	16,667	
Arch Pieces	....	16	1 × 12	"	50,000	
Track Shores	250	4′ 1″	2 × 10	"	1,702	
Packing Blocks	500	1½′	6 × 12	"	4,500	
Arch Posts	280	18′	6 × 12	"	30,240	
					292,322	292,322
Total amount of Timber						323,287

324 feet per lineal foot of Bridge.

BILL OF WROUGHT IRON FOR 1000 FEET OF MILITARY RAILROAD BRIDGE.

Names of Pieces.	No. of Pieces.	Length in Wood.	Total Length.	Size of Iron.	No. of lbs.
Chord Bolts	2,000	1′	1′ 2¼	¾″	3,625
Bolster Bolts	324	3′	3′ 2¼	"	1,560
" "	64	2′	2′ 2¼	"	212
Bottom Lateral Rods	85	19′	19′ 6″	1¼″	6,915
Top Lateral Rods	85	18′	18′ 6″	"	6,560
Arch Rods	480	....	....	"	29,000
Track Stringer Bolts	250	5′ 9″	5′ 11¼	1″	3,953
¾ Nuts	2,388	....	....	....	796
1″ "	500	....	....	....	500
1¼ "	1,800	....	....	....	1,950
1¼ "	480 for	adjustment	of Arch Pos	ts,	720
Heads for ¾ Bolts					600
Total Wrought Iron					56,391

BILL OF CAST IRON.

Names of Pieces.	Number of Pieces.	No. of Pounds.
¾ Washers	4,776	3,582
1″ "	500	750
1¼″ "	1,800	4,550
Lateral Shoes	840	7,200
1½ Washers	480 for adjustment of Arch Posts.	1,680
Total Cast Iron		17,762

Total Weight of Bridge, 1000 lbs. per lineal foot.

False-Works.

It is usual, in the construction of bridges, to support the structure until it becomes self-sustaining by means of scaffolding, called false-works. This scaffold consists of light trestles, placed 12 or 15 feet apart, upon which planks are laid to facilitate the distribution of material; but if the stream to be bridged is deep and rapid, or if the elevation of the grade above water-line is very great, the construction of a suitable scaffold may require more time and material than the bridge itself.

As time is an important consideration in military operations, it is desirable that a mode of constructing false-works should be devised that will admit of the preparation of the parts in advance, without regard to the locality; which can be readily adapted to any span or elevation without change of parts, and which neither freshets nor insecure foundations between abutments can affect.

The suspension principle is obviously the only one that will fulfil these conditions; and there is a peculiar propriety in its application for military purposes, from the fact that the same equipage which is required for scaffolding for a railroad bridge will also furnish the means of constructing, with great rapidity, a foot-bridge for the passage of infantry, or a road-bridge for cavalry, artillery, or wagon-trains.

Description of Suspension Scaffold.—(Plate VII.)

The supports of each span consist of eight wire ropes, each one inch and a half in diameter; four on each side, securely anchored at the ends, and allowed to hang with a deflection of about one-tenth of the span.

The ropes should be in lengths of about one hundred feet each, and, being furnished with a swivel-link ten inches long, any desired length of cable is obtained by connecting the ropes, by means of a bolt, with a right and left screw, passing through a nut in the inside of the swivel-link. The advantage of this arrangement is, that the short ropes are easily handled and transported, and the recurrence of the swivels at intervals of moderate length affords facilities for bringing the ropes to an equal tension and length. (Plate VII.)

Military railroad bridges are usually required to be constructed on the sites of former bridges destroyed by the enemy, in which case the piers and abutments generally remain nearly or quite perfect.

The first cable is drawn across the piers by means of a rope, which has been previously pulled over by a wire. When the cable has been fastened on the opposite side, a man can transport himself to the tops of the piers either by climbing along the rope, or, if unaccustomed to such operations, as is generally the case with soldiers, he can work himself across safely by means of a piece of board suspended from a pulley or short roller running along the cable.

The man who is sent over the line should take with him a strong cord, with which to draw up to the top of the first pier a rope ladder; two strong iron pins being

driven between the joints of the masonry, and the rope ladder fastened securely thereto, he can take the cord and proceed, by similar means, to the second, and successively to the remaining piers, to each of which a rope ladder will in like manner be attached.

Having thus established communication, by means of rope ladders, with the tops of the piers, the cable which has been used for the purpose can be thrown off, as it would interfere with the placing of the wall-plates.

The wall-plates (Plate IV.) are raised into their positions by means of very light shears, constructed of two sticks of timber, 3 inches square; the lower ends are pointed with iron, and a single stay-rope, fastened to a pin driven into a joint of the masonry, holds it in place. (See figure.)

The wall-plates are fastened by spiking plank across the tops after they have been placed in position, and between the plates other pieces of plank are placed, which are fastened to the masonry by driving large spikes or iron pins into the joints.

After the wall-plates are in position, the cables, which have been previously carried across at the bottoms of the piers, are raised, by means of the shears, into their positions, four on each side; one end being securely anchored on the side from which the material will be brought, the other end fastened temporarily.

The cables of the first span are next adjusted to hang at the proper level. This can generally be done most readily by placing a surveyor's level in such position that the telescope will be at the same height as the lower part of the cables. The cables can be readily drawn up or slackened by the aid of handspikes, which

hold the ropes by means of an eccentric cam, or some equivalent arrangement.

Where the cables of the first span are adjusted to hang at the proper elevation, they are held in position and prevented from slipping by staples driven into the wall-plates, and the remaining spans are then successively adjusted as rapidly as possible.

Placing the Sills.—(Plate VII.)

The sills or cross-timbers, which lie across and in contact with the cables, are placed in position successively from one end, by spiking to the ends of the first sill two pieces of plank 15 feet long. By means of these planks the first sill can be pushed out from the abutments, sliding it along the cables until it is in position; the planks are then spiked to the wall-plate on the abutment.

A second sill is then pushed out in like manner, fifteen feet beyond the first, and the ends of the plank spiked to the first sill. Thus each sill, as it is successively laid, will be connected with the preceding one by planks, over which men can walk, and a footway can soon be extended over all the spans.

Erecting the Trestles.

The legs of the trestles consist of pieces of timber 6 inches square, with holes bored about 3 inches apart. Near the top, and on the sides, are bolted two pieces of plank, forming a cap. The object of this arrangement is to place the cap at such elevation that its top will be on the level of the bottom of the lower chord. These

trestles, being short and light, can easily be put together on the ropes and raised into place. Light braces, nailed on the sides, will keep them in position; or, instead of this, the posts may be allowed to project below the cables, as is represented in the plan. The whole scaffolding is light, portable, and can be used without alteration many times, in different localities and for different spans.

Transportation and Distribution of Material.

The material will generally be transported on cars, and the cars should be loaded in the precise order in which the pieces are to be laid upon the scaffold, and in the same proportion in which they are required for use. For example, the planks which form the top chords, being the last to be put in position, must be the first to be laid upon the scaffold, in order that parts required sooner may be placed on top of them, and may be accessible without extra handling. These upper chord-planks are laid on the scaffold side by side, forming a gangway 8 feet wide. This will give abundance of room to pass, and the rule of keeping to the right should be observed by the gangs or squads going and returning, so as to avoid confusion and delays.

The material being distributed uniformly along the bridge in the proportions required for use, the work of putting the trusses together can be commenced. The lower chord-planks should be placed in position as soon as brought upon the false-works—there is no necessity for handling them twice.

When the road-way runs upon the upper instead of the lower chord, the arch suspension-rods may be omitted,

and posts placed on the arch which will support that upper chord.

Two modes of adjusting the posts are represented in Pl. VI., Fig. 3. The first consists in inserting an eye-bolt through the arch, and another nearly at right angles to it through the post, by means of which the post can be tightened and held in place. A block nailed behind the post, across the arch, will afford additional security. The other plan consists in using posts and suspension-rods both, and allowing the end of the rod to pass into the lower end of the post, upon which a nut and washer is placed. (See Plate VI., Fig. 4.)

Truss Bridge for Long Spans, constructed of round sticks.—(Plate VIII.)

The mode of constructing a military railroad bridge of plank and boards, which has been described, is, perhaps, that which will permit a truss capable of sustaining a train to be put together in the shortest possible time after the materials are delivered on the ground; but the whole bridge truss is composed of sawed lumber. It may sometimes be difficult to procure a sufficient amount of plank for such a truss, and, if procurable, there may not be facilities for transportation. Cases may, therefore, occur where it would be desirable to reduce the transportation to a minimum, and use, as far as possible, the material which the forest may afford. Plank for the lower chords cannot readily be replaced by any other material,* and must be carried by rail or wagon. But the top chords, braces, counter-braces, floor-beams, track-

* Boards nailed together may, in some cases, be substituted, but great care must be exercised in packing them. They should be keyed at the ends against resisting abutments, and may be pitched to increase the friction.

strings, and lateral braces, may all be made of round sticks.

Construction of the Truss.

Lower Chords.—The lower chord of each truss consists of eight or ten rows of chord-plank, each 3 inches by 12 inches, packed closely together, and breaking joint at intervals of 4 feet. This will form a continuous line of chord 24 or 30 inches wide and 12 inches deep.

The chord-bolts pass horizontally entirely through the chords, two bolts, placed in a vertical line, at intervals of 4 feet between each pin.

The chords are packed, after the chord-bolts have been screwed, by boring vertical holes and driving pins 1½ inch into them, at distances alternately of 3 and 6 inches from the bolts, the pins being driven in the joints between the chord-planks as a substitute for keys. At a distance of 2 feet from the line of the chord-bolts, a tree-nail should be driven horizontally through the chord-planks, and wedged tightly at each end.

No holes are to be made through the chords for the truss-rods; they must pass on the outside, extending from a saddle on the top of the top chord to a stirrup-piece on the under side of the bottom chord.

Height of Truss.—The height of truss should be the same as in the former plan, being determined by the condition, that the distance from the top of the rail to the bottom of top lateral braces shall be 16 feet.

Truss-rods.—The truss-rods are of the usual dimensions allowed in Howe trusses. For spans of 150 feet, the end rods should be 2 inches in diameter; the middle rods 1½ inch.

The rods are all of equal length: the bridge will be framed without camber.

Braces.—The braces are round sticks, 10 inches in diameter at the end, and 8 inches in the middle panels, placed in pairs; the counter-braces, 8 inches round, pass between. The braces are cut at the ends with a shoulder, the vertical part about four inches; the horizontal part resting against the chords. Instead of angle blocks, rectangular blocks, about 6 by 12 inches, are notched, 1 inch in the top and bottom chords, and well spiked to them. Plates of iron placed under the ends of the braces and counters would be an improvement, and would increase the durability; but as durability is not regarded as of paramount importance in military bridges, they may be omitted.

Arch Braces.—From the bottom of the braces of the first panel to the top of the braces of the second panel, extending over the space of both the first and second panels, arch braces should be inserted. There being no rods through the chords, a very favorable opportunity is afforded of putting in the arch braces, and they add so much to the strength of the truss that they should not be omitted. These braces should be three in number, and about nine or ten inches in diameter, slightly flatter where they come together.

Lateral Braces.—The lower lateral braces can be constructed of the 5 or 6 inch sticks, supported by pieces spiked to the inside of the chords; the ties being iron rods, as in the Howe plan. The top lateral braces may be spiked on the top of the chords, and the ties may also be round sticks.

Floor-beams.—The floor-beams are of round timber, 12 inches in diameter; placed 4 feet apart.

Track-strings.—Track-strings are flatted on two sides, 10 inches deep.

Top Chords.—The top chords are composed of three or four lines of timber, flatted on two sides, and packed so as to break joint. They are bolted with one chord-bolt, every four feet, with intermediate treenails; but the vertical pins required in the lower chords may be omitted.

Raising the Truss.

The scaffolding for the lower chords is constructed as in any other bridge, but the absence of angle blocks, and the fact that the truss-rods do not pass through the chords, permits the scaffold for the top chords to be raised very conveniently. It is only necessary to raise trestles, consisting of two upright and one cross piece, resting on the blocks which are notched into the top of the lower chord. On the tops of the trestles, the blocks which are to be notched into the lower side of the top chords are pinned; planks laid across the top form a scaffold, by the aid of which, the top chords are framed and put in place. To cut the notches on the under side, it will be necessary to mark them and turn them over; or, the top chord may be framed by measurement, packed, then taken apart and raised.

The saddle-pieces over the top chord should extend entirely across, the outside rods, braces, and connections put in, after which the temporary scaffold trestles may be taken down, and the inside rods inserted through the saddle and stirrup-blocks, all of which should be long enough to extend from side to side.

The braces and counters will be all of the same length, if the panels are laid off equally, and great care should be exercised in the measurement.

This arrangement will make a very simple and inexpensive truss, requiring transportation only for the iron rods and lower chords; but it will probably require three or four times as many hours to frame and raise it, as the plank truss previously described.

Floating Railway Bridges.—(Plate IX.)

An application may be made of floats, constructed in the manner described under the head of *Floating Docks and Warehouses*, which is believed to be entirely new, and may, in many cases, offer very great advantages.

The application referred to consists in using them in the construction of floating railway bridges, for the passage of locomotives and trains

For this purpose, peculiar arrangements are required. The floats must be large, and connected by trusses, which, if continuous, must be neither too rigid nor too flexible, but such as will, without injury, permit of the undulating motion caused by the variable load, as in the Niagara Suspension Bridge; or, if rigid, must be disconnected at the points of support.

The advantages possessed by such a structure are numerous and great.

It could be built and put together in sections along shore; then towed or warped into position, and secured by piles or anchors.

It could be built in sections at one place; then transported many miles, and put together in another.

It could be used in deep rivers, and would form a good communication where piers could not be constructed, or piles driven.

It could, after being constructed, be much more expeditiously placed than any other kind of railroad bridge.

In navigable rivers, it could be provided with draws, manœuvred more readily, and constructed less expensively, than any other form of bridge.

The same principle is applicable to structures of considerable permanency, the floats and trusses being made of iron.

It is also applicable to bridges for ordinary roads across streams, where pile or pier bridges cannot be constructed, or where the expense of such structures would be too great.

The disadvantages are:

The variable level of the road-way, which requires a pivot bridge at the ends to connect it with the shore, and would lead to great inconvenience, where, as in some of the streams of the South, the difference between high and low water is more than fifty feet. In such cases, it is preferable to build wooden piers in the floats, sink them, and have the bridge at a constant level, to be determined by previous soundings.

The liability to be carried away by ice-freshets. But this objection also applies to all other bridges not constructed on piers of solid masonry. If carried away, the floating bridge could generally be divided into sections, and towed back again; and considerable protection could be afforded by sinking strong crib ice-breakers above the floats, to which they could be fastened. The ice sliding

over the ice-breakers, and falling off upon each side, would be so broken as generally to pass the intervals between the floats.

Plate IX. represents a floating bridge. The floats which support it are 100 feet long, 20 feet wide, and require 125,000 lbs. to sink them one foot, provided the weight is uniformly distributed. If the floats are placed 100 feet apart, the weight of an ordinary bridge-truss, at one-half ton per foot, would be 100,000 lbs., which, with the weight of the float itself, would cause an immersion of 17 inches.

The weight of a 25-ton locomotive directly over a float would sink it 5 inches, and with half the weight of a train extending across one span the depression would be 6 inches more, making 11 inches difference of level between the float upon which the locomotive rested and the next in advance, which at that instant was unloaded.

If the locomotive when in this position was in a state of rest, and the truss be supposed straight and rigid between the two floats, the power exerted in starting would be equal to that required on a grade of forty-eight feet to the mile; but as soon as the engine moves forward, the weight commences to press upon the float at the other end of the span, and the grade becomes less until, before reaching the next float, it is slightly descending.

As the momentum of the train will carry it beyond the points of maximum resistance, the power exerted by the engine will not greatly exceed that required on a level.

Can the trusses be so constructed, that no injury will result from the undulations of the floats? Certainly; the

plan represented in the plate fulfils this condition. At the bottom very little strain will be thrown upon the chords, even if connected; but they may be cut apart between the two trestles, and simply connected by pieces bolted on the outside, with a single bolt over the trestles, thus permitting rotation around the bolt as a pivot. At the ends of the top chords the joints will open and close with the undulations of the floats, and the pieces by which they are connected should be slotted, so as to accommodate this movement.

In erecting this bridge, it will be convenient to place the alternate spans upon the floats near the shore, tow them to their places, and anchor them, leaving the exact spaces required for the intermediate spans.

The intermediate spans can then be put in position, by the arrangements and manœuvres now to be described.

The span being put together upon false-works, at an elevation above the water about equal to that which it is to occupy in the bridge, two floats partly filled with water are brought under it, at distances from the ends somewhat greater than the half width of the permanent floats. The water is then bailed or pumped out, and as the floats rise they will lift the bridge off the false-works. It can then be floated in position and dropped into its place by simply letting in the water.

Two floats, 15 feet by 50 feet, would carry a span of 100 feet, with 1 foot displacement. The manœuvre of raising and putting the span in place would only require one foot and a half of water to be pumped out. A still more expeditious mode of construction would be secured by using two floats to each span, one at each end.

In a stream with a sluggish current, soft and compressible bottom, and great depth of water, which would render the construction of piers by coffer-dams, or other ordinary resources of engineering, impossible, it would sometimes be a very economical and very excellent plan to construct floats of great capacity, the bottom composed of at least two layers of squared logs, touching each other, and covering an area several feet greater than the area of the float, which may be, if necessary, 100 feet in the direction of the stream, with a width of 30 or 40 feet. In this float very stout wooden piers could be constructed, of vertical posts, about 2 feet apart, well capped, and braced in such manner as to distribute the pressure over the whole base. The float, being moved into its place, and held by ropes, if the depth of water was too great for piles, would be gradually sunk; the platform on top being placed at such elevation, as determined by previous measurement, that its upper surface would be a short distance below the surface of the water.

On the top of this platform, piers of iron, stone, or timber could be erected, the pressure being distributed over so broad a base as to afford a fair prospect of stability.

For military bridges the piers could be built in advance, floated to their places, and then sunk. The most convenient mode of putting on the superstructure would be by floating it in sections of one or two spans, mounted on trestles of sufficient height, and lowered by letting water in the floats, which could afterwards be removed by pumping.

Military Railroad Board Suspension-Bridges.

Experiments made at Alexandria in March, 1863, indicate the practicability of constructing suspension-bridges with board catenaries of sufficient strength to carry railway trains. By this mode of construction, bridges can be erected without false-works or scaffolding, and in a manner which is both expeditious and economical.

In the construction of a board suspension-bridge for railroad purposes, it is necessary to commence the catenary by nailing together three series or thicknesses of boards, breaking joint, and securely fastened. When a sufficient number have been attached to form a span, the board catenary is drawn across the stream, placed in position, and anchored. Other boards are then added, so as to give the requisite number to resist the tension, data for the calculation of which have been given by the experiments conducted at Alexandria, under the direction of the writer, by Adna Anderson, Esq., engineer of construction on the military railroads of Virginia.

When a sufficient number of boards have been added to the catenary to secure the necessary tensile strength, holes must be bored for pairs of half-inch bolts, at intervals of a foot, in the length of the catenary, and the bolts inserted, taking care to place large washers under the head and nut of each bolt.

Having tightened the bolts and compressed the layers of boards as much as possible, spikes, sufficiently long to pass through the whole series of boards, are driven at intervals of 4 inches.

The size of the catenary should be increased towards

the ends in proportion to the increase of strain at these points.

When the catenary has been finished and securely anchored, the bridge is completed by placing bents, at intervals of about 12 feet, across the caps of which the stringers for the support of the track can be laid. A trussed suspension-bridge may be formed by laying a top chord upon the bents, securely connected by bolts and keys to the catenaries at the ends.

Lateral, diagonal, and other bracing can be constructed of plank, spiked or bolted on the sills, caps, and legs of the bents.

Portable Railway Trusses.

The experiments on board catenaries and board trusses, which are described in the report of Adna Anderson, Esq., were so satisfactory, that it was considered expedient to construct a considerable extent of portable bridging, in spans of 60 feet, with a view to facilitate the operations of the Army of the Potomac, and aid in the more rapid reconstruction of any railroads, or portions of railroads, that might be embraced within the field of its operations.

About 1,000 feet of this bridging was prepared, but no opportunity has been presented of using it in the field.

The trusses are 60 feet long, and 6 feet deep in the middle.

The top chord is nearly straight, having only a camber of 3 inches.

The lower chord is an arc of a circle, composed of nine boards, packed so as to break joint, bolted, at intervals

of 1 foot, with two half-inch bolts, and spiked at intervals of 4 inches. The edges of these boards were adzed to a plane surface, and other boards were then nailed to the edges and dressed to the form of the curve, to give a proper finish.

. The board arch formed a catenary, and was connected with the top chord at the ends by filling the angular space for a distance of about 6 feet with a block of hard oak, to which the arch and chord were attached by spikes and bolts, the top chord being stepped into the oak block. The braces and counters were of 4″ by 5″ scantling, and two round rods, 1 inch in diameter, passed through the truss at each panel.

Two of these trusses were placed parallel to each other, at 10 feet apart, braced with plank, and loaded to the extent of two tons to the lineal foot, in addition to the weight of the bridge, which weight was sustained for several hours without injury, examination proving that the boards which formed the catenary had not slipped perceptibly upon each other.

These trusses possess the quality of portability in a high degree. Six of them can be loaded on a platform car, and by placing an empty car between each pair of loaded ones, the transportation presents no difficulty These trusses were loaded on cars at Alexandria, the cars run on barges, the barges towed to Acquia Creek, the cars landed and sent to the Rappahannock, without moving the trusses on the cars.

In using these trusses, it was proposed to transport them by rail as far as the track was perfect, then haul them by oxen and timber wheels to the sites of the bridges to be reconstructed, even to distances of twenty-five or

thirty miles, where they would be hoisted by pulleys on the tops of wooden piers, connected by bracing of 2-inch plank, and the ties laid directly on the top chords.

The trusses could be dragged by oxen on the common roads by placing a shoe under the portion in contact with the ground, or by hoisting both ends on wheels.

Wooden Piers for Military Truss-Bridges.—(Plate XIII.)

The portable bridge-trusses were designed with especial reference to facility of transportation and rapidity of erection; but, being constructed in advance, without a knowledge of localities or measurement of dimensions, it is not to be supposed that they would exactly fit the recesses or bridge-seats of the structures which they were intended to replace.

The portable trusses have been made in lengths of 60 feet. Allowing 2 feet at each end for the supports on the piers and abutments, would leave 56 feet as the clear spans for which they are best adapted; but if the span should be less than 56 feet, it is only necessary to place the wall-plates or sills a sufficient distance back from the faces of the abutments to increase the span to the required extent. If the masonry of the abutments should be so high as to come in contact with the curve of the truss, one or two courses can be thrown off, so as to make room.

If, on the contrary, the span should be greater than 56 feet, and not more than 116 feet, a wooden pier can be erected in the middle, dividing the interval into two spans; and if greater than 116 feet, the interval may be divided into three or more spans. Sometimes two spans of the portable trusses and one or two short spans, with

simple girders, may be found to be the most expeditious mode of construction.

Suppose a span of 140 feet. This is obviously too long for two of the 60 feet trusses, and too short for three of them. In this case, the best arrangement would be, two wooden piers placed so as to give 56 feet clear span in the middle interval, and two end spans of 56 feet, obtained by moving the sills on which the trusses rest back from the face of each abutment a distance of 18 feet.

Where there are continuous spans, with stone piers, the intervals of which are not adapted to the lengths of the portable trusses, it is still possible to construct a bridge, without inconvenience or delay, by placing the trusses in such manner that the ends of adjacent spans, instead of abutting end to end, will lap over and pass each other. For example, in one span the trusses may be placed 8 feet apart, in the next 10 feet, and so on alternately. This arrangement might be considered objectionable, on the score of appearances; but this is of little consequence in a military bridge, where rapidity of construction must be the governing consideration.

In the use of the portable bridge-trusses, the construction of wooden piers will very frequently be necessary. The plan should be such as will be adapted to any locality, and permit of the erection of these structures in the shortest time possible.

After careful consideration of various forms of piers which would fulfil the required conditions, a plan was devised which appears to be exceedingly well adapted to the purpose for which it is designed.

Description of Pier.—The pier for the support of the portable trusses consists of a combination of bents, all of

which are of uniform size, and can be put together without any previous measurements, or determination of levels or heights.

Each bent consists of two round sticks, from 9 to 12 inches in diameter, and 20 feet long. These sticks are laid parallel to each other, and 6 feet apart; the ends are cut square. Holes, 2 inches in diameter, are bored in each end to a depth of 6 inches, into which dowels of hard wood are to be inserted, when the bents are put in place. Across the middle a piece of plank is spiked, and other pieces in the direction of the diagonals of the two rectangles thus formed. The caps and sills are formed by pieces of plank of uniform size, cut and bored by a pattern, so as to be interchangeable. This principle of uniformity of dimensions is an important one. The legs of the bents, the caps, sills, braces, dowels, and, as a consequence, the bents themselves, are all of precisely similar dimensions, and can be taken up and used without measurement or selection, there being no possibility of error from mistakes or want of skill.

The piers consist of a central portion, the plan of which is a rectangle, with sides of 6 and 10 feet, the supports of which are carried up vertically from the bottom, giving an area at the top of the pier of 6 feet in width and 10 feet in length. This central portion is braced, on each of the four sides, by other bents placed in inclined positions, and connected with the central portions at intervals of 10 feet. (Plate XIII.)

To erect a pier, two of the bents are placed in position vertically, and 10 feet apart; pieces of board or plank are nailed or spiked on the sides, to hold them until braced. Across the middle of each bent a plank has been

spiked, and across the top the cap has been placed before raising, and secured by dowel-pins. These planks and caps serve as supports for scaffold-planks, which can be laid across them, and by means of which the ties and braces required to connect the bents and complete the middle portion of the pier can be readily put in place.

The construction at this stage of progress exhibits a portion of a pier, consisting of four vertical posts, 20 feet high, placed at the four corners of a rectangle 6 feet wide by 10 feet long, the posts connected at top by caps, and at bottom by sills, also by ties in the middle, which form rectangular panels, the diagonals of which are braced.

On the top of this first section a pair of light shears, carrying a pulley-block, is placed, the rope passing over a drum at the bottom. By means of these shears the bents for the second section are raised; the holes in the bottom of the posts are placed over the dowels, which project from the tops of the posts of the first section; and the second section is finished in a manner precisely similar to the first.

Upon the completion of the second section the shears are raised to the top, and a third, and, if necessary, a fourth and fifth section added, with great rapidity, in a similar manner, simply by a repetition of the process previously described.

When the last section has been placed in position, the posts will generally project above the proper level; the excess in height must be sawed off, and caps of square timber, 12 to 16 feet long, secured by dowels, on the upper ends of the posts. These timbers will be 6 feet apart, and form the tops of the piers on which the trusses rest.

If the piers are very high they may be stayed, during the process of erection, by ropes, until the braces are put in place.

A high and narrow rectangular pier, 6 feet wide by 10 feet long, with vertical posts at the four corners of the rectangle, would possess but little stability; and it becomes necessary to support it by four inclined series of bents, one on each side, the inclination of the bents at the ends, or up and down stream, being an inch and a half to the foot, and at the sides, or in the line of the bridge, about half that amount.

These bents are of the same dimensions as those used for the central portion. As soon as the height of the pier can be ascertained, the width of the base is determinable, and the inclined bents can be rapidly raised, put in position, and braced, without in any way retarding or interfering with any of the other operations.

As soon as the width of the base has been determined, and one or more stories of the central portion of the pier placed in position and braced, the inclined bents may be set. They are raised in the same manner as the vertical bents, and are of the same size, and identical in every particular. Of course, in consequence of their inclination, the joints will not be in the same horizontal planes with the joints of the vertical posts; but the variation is so slight as to be of no consequence, so far as affects the strength, and not even perceptible to the eye when the stay-planks, which connect the inclined with the vertical portions of the pier, have been spiked upon them.

The cap timbers, which lie longitudinally over the vertical posts of the piers, also project over and are

pinned to the inclined timbers of the end bents which lie in the same vertical planes.

On the sides, the inclined bents being of the same size as those at the ends, and the posts consequently 6 feet apart, while the vertical posts of the pier on the sides are 10 feet apart, these vertical and inclined timbers will not be in the same vertical planes parallel to the direction of the bridge; but this is productive of no disadvantage. The tops of the inclined will be pinned under the cap, at a distance from the vertical posts of 1 foot, so that there will be three timbers supporting each end of each cap, and carrying the pressure directly to the foundation in straight lines.

This description, with an examination of the accompanying plan and elevation (Pl. XIII.), will be sufficient to render the mode of construction intelligible.

If the foundation is compressible, the weight must be distributed by means of long timbers forming a platform on which the bents can rest.

To place the portable bridge-trusses in position.—There are several manœuvres by which the portable trusses can be placed in position.

If the bridge consists of several spans, with a number of piers, the most expeditious mode of construction would be found to consist in building all the piers at once, dragging or floating the trusses to the sides of the piers, and then hoisting, by means of shears and pulleys, to the tops.

If the height of the piers is not great, inclined timbers may be laid against them, forming skids on which the trusses may slide into position.

Wire ropes may be thrown across the opening, and

securely fastened. The trusses may be connected and a span of bridge completely finished, except the track, while on the bank at one end of the bridge. Three or more rollers, 12 feet long, with flanges on the ends to prevent them from running off the ropes, may be attached to the bridge, by means of which it may be pulled over the ropes and drawn into its place, after which the ropes may be slackened, removed, and used for the next span.

Several spans may be erected successively in this manner. When one is in place, the next will readily roll over it by means of the rollers previously described.

Other manœuvres, described elsewhere, will be applicable to single spans of the portable trusses, and permit them to be placed in position rapidly, and without false-works or scaffold.

UNITED STATES MILITARY RAILROADS,
OFFICE OF CHIEF ENGINEER OF MILITARY RAILROADS OF VA.,
ALEXANDRIA, VA., *May* 27, 1863.

Brig.-Gen. H. HAUPT, *Chief of Construction and Transportation U. S. M. R. Roads.*

SIR :—In compliance with your instructions, I caused to be built from the sketch furnished by you, and tested at the bridge-yard in Alexandria, a board suspension-bridge and two portable arched truss-bridges, for military roads; also a portable truss-bridge, for military railroads; and submit the following statement of their construction, and the tests to which they were subjected.

I.—Board Suspension-Bridge.—(Plate X.)

This was supported by two cables, each 6 inches by 12, made by nailing together pine boards 1 inch thick.

They were laid with care to properly break joints; were nailed together with tenpenny cut nails, 4 inches apart; and 6-inch cut spikes were driven through the boards forming the cables at intervals of 6 inches. At the ends, each cable was fastened to the abutments by spreading apart the boards in the shape of a fan, inserting between them, and strongly nailing, wedge-shaped pieces of wood. (Fig. 3.) Posts of the proper length were placed upon the cables, 12½ feet apart, dividing the space into panels of that length, and braces were spiked to the top of one post and the foot of the next. (Fig. 2.)

The posts were connected at top by caps, on which stringers were laid to support the floor.

BOARD SUSPENSION-BRIDGE FOR MILITARY ROADS.

Clear Span, 100 *feet.—Versed Sine*, 10 *feet.*

MATERIALS USED.

For what Purpose.	No. of Pieces.	Length.	Size.	Contents B. M.
Cables	....	....	1″ × 12″	1,850
Wedges	10	5′	2 × 12	100
Posts	4	5′	8 × 9	120
"	4	7′-9″	8 × 9	186
"	4	9-6	8 × 9	228
"	2	10	8 × 9	120
Caps	9	9	8 × 9	486
Braces	12	15	8 × 10	450
"	8	14-6	8 × 10	290
"	4	18-6	8 × 10	185
"	4	12	8 × 10	120
" Sway	4	8-6	8 × 8	68
" "	4	10	8 × 8	80
" "	4	11-3	8 × 8	90
" "	4	11-6	8 × 8	92
Stringers	....	410′	6 × 12	2,460
Nails in Cable	20,160	....	10d.	262 lbs.
Spikes	600	6 inch	....	110 "
Braces	224	"	....	40 "
Sway	84	"	....	15 "

This bridge was tested by loading it with iron disposed in three piles, covering about 86 feet of its length, or within 7 feet of each abutment.

The weight of the pile on the middle of the bridge was 33,600 pounds, and of each pile near the ends,

25,200 pounds. Total weight on the bridge, 84,000 pounds, or at the rate of 840 pounds to the lineal foot.

The abutments constructed for the test proved insecure, and as the weight was applied they slipped toward each other on the foundations.

The fan-shaped ends of the cables were compressed by the strain, so as to slip to some extent between the timbers by which they were fastened.

Both causes combined produced considerable sagging at the centre. The boards composing the cables were slightly pulled apart at the joints, in some instances one fourth of an inch; and the cables assumed a polygonal form under the strain; but no indications of immediate breakage were perceptible.

II.—Portable Arched Truss-Bridge for Military Roads.

BRIDGE No. 1.

The trusses for this bridge were constructed of the form shown in Fig. 1, Pl. XI.

Their extreme length was 60 feet; clear span of opening, 54 feet; greatest depth at centre, 6 feet 11 inches.

The chords were made by nailing together pine boards 1 inch thick by 12 inches wide; the upper chord being 5 inches, the lower chord 6 inches thick.

The boards were nailed every 4 inches with tenpenny nails, and 6-inch cut spikes were driven through the lower chord at intervals of 6 inches.

The truss was divided into ten panels, each 6 feet long, with a post and suspension-rod at the end of the panel. Main and counter braces were in all the panels,

except at the ends, which, for 4½ feet, were filled with solid blocks. To the blocks, the boards forming the chords were nailed, and the whole bolted through from top to bottom, with 5 bolts at each end.

MATERIAL IN BRIDGE No. 1.

LUMBER.

For what Purpose.	No. of Pieces.	Length.	Size.	Contents B. M.
Lower Arched Chord	....	...	1″ × 12″	762
Upper " "	....	....	1″ × 12″	685
Blocks in end Panel	4	4′	....	144
Posts	4	2′–3″	2″ × 12″	18
"	4	3–10	2″ × 12″	31
"	4	5–	2″ × 12″	40
"	4	5–10	2″ × 12″	46
"	2	6–	2″ × 12″	24
Braces, Main	4	2–3	2″ × 12″	18
" "	4	6–7	2″ × 12″	53
" "	4	7–4	2″ × 12″	58
" "	4	8–	2″ × 12″	64
" "	4	8–4	2″ × 12″	67
" Counter	4	6–7	2″ × 12″	53
" "	4	7–4	2″ × 12″	58
" "	4	8–	2″ × 12″	64
" "	4	8–4	2″ × 12″	67
" Lateral	36	9–	2 × 8	384
" Sway	4	6–2	1½ × 8	25
" "	4	6–10	1½ × 8	27
" "	4	7–5	1½ × 8	30
" "	4	8–	1½ × 8	32
" "	2	8–3	1½ × 8	17

IRON.

For what Purpose.	No. of Pieces.	Length.	Size.	Weight.
Suspension-Rods	4	3–3	1¼ diam.	68
" "	4	5–3	1¼ "	96
" "	4	6–5	1¼ "	112
" "	4	7–3	1¼ "	124
" "	2	7–5	1¼ "	66
Bolts	4	1–6	1″	20
"	4	1–11	1″	24
"	4	2–1	1″	26
"	4	2–7	1″	32
"	4	2–10½	1″	34
Washers, Cast Iron	76	....	....	218
Nails in Bottom Chord	5,680	....	10d.	74
" in Top "	4,544	....	"	59
" in Lateral Braces	888	....	20d.	28
" in Sway "	98	....	"	9
Spikes in Bottom Chord	360	....	6-inch	65

This bridge was tested by laying a railroad track across, and running to its centre a car loaded to weigh 48,000 pounds.

Iron was then piled on the bridge until it gave way.

As weight was applied, the deflections were noted at the centre, and at a point each side of the centre half way to the end.

In the following table, No. 5 denotes the centre, Nos. 3 and 7 the other posts where observations were taken:

PORTABLE ARCHED TRUSS-BRIDGE No. 1.

Tested March 11, 1863.

No. of Trial.	Weight on Bridge.	Deflections at No. 3.	Deflections at No. 5.	Deflections at No. 7.	Remarks.
1	52,200 pounds.	$1\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{1}{8}$	
2	60,600 "	$2\frac{3}{8}$	$2\frac{5}{8}$	$2\frac{3}{8}$	
	60,600 "	$2\frac{7}{8}$	$3\frac{1}{8}$	$2\frac{7}{8}$	After standing three hours with the load.
3	64,800 "	$3\frac{3}{8}$	$3\frac{1}{4}$	$3\frac{1}{8}$	
4	78,200 "	$3\frac{5}{8}$	$4\frac{1}{8}$	$3\frac{5}{8}$	
5	81,600 "	4	$4\frac{5}{8}$	$4\frac{1}{8}$	
6	90,000 "	$4\frac{1}{4}$	$5\frac{1}{8}$	$4\frac{3}{8}$	
7	98,400 "				After standing five minutes, "broke." Total weight, 49 tons 400 pounds.

The span being 54 feet, the weight under which the bridge gave way was 1,822 pounds per lineal foot.

Before breaking, the upper chord buckled considerably between posts Nos. 3 and 4, but finally failed by the lower chord pulling apart at the end of a panel where the suspension-rod passed through it.

PORTABLE ARCHED TRUSS-BRIDGE NO. 2.

The trusses of this bridge were constructed similar to those of No. 1, with the following additions:

1. The boards forming the lower chord were covered with a mixture of pitch and tar before they were nailed together.

2. Half-inch bolts in pairs were put through the lower chord each foot of its length, and the nuts tightly screwed up, to press the boards together and hold them in place.

3. On both sides of each chord a board, 1 inch by 12,

was strongly nailed. The edges of the board were trimmed to fit the curve of the arched chord.

The materials were the same as in Bridge No. 1, with the following added:

240 feet B. M. 1-inch boards.
128 bolts in lower chord, 7″ long, ½″ diameter.
4,320 tenpenny nails, wt. 55 pounds.
2¾ bbls. pitch.
1½ bbl. tar.

Fig. 4, Pl. XI., is a view of the under side of the lower chord, and Fig. 5 is a section of the same.

EXPERIMENTS.

A SERIES of experiments was made on the Portable Arched Truss No. 2, similar to those on No. 1. A car was loaded with railroad iron, and pulled forwards and backwards over the bridge by means of ropes—the load being gradually increased until the truss broke.

Twenty-four experiments, with increasing weights, were made upon this truss. In the twenty-third experiment, 190,380 pounds were allowed to stand on the bridge for two hours; the weight was then removed, and deflections noted.

In experiment No. 24, the weight of 190,380 pounds was allowed to remain for an additional period of six hours, when the bridge broke down.

The breaking weight was 3,525 pounds, or 1 ton 1,525 pounds per lineal foot.

Experiments on the Holding Power of Ten-penny Nails.

Experiments were made, in connection with the tests of these bridges, to determine the holding power of nails, when one board was nailed to another with a given number of nails to the square foot, and then torn asunder by a force applied in a direction parallel to the length of the board, or at right angles to the direction of the nails. The annexed table gives the results obtained.

Test of the Strength or Holding Power of Ten-penny Nails.

Number of Nails.	Nails in one sq. ft.	Area of surface in contact.	Condition of surface.	Kind of plank.	Kind of block.	Breaking weight.	Breaking weight per nail.	Number of trials.
		sq. ft.				lbs.	lbs.	
8	8	1	....	Pine	Pine	2940	367½	1
8	8	1	....	Pine	Pine	3360	420	2
8	8	1	....	Oak	Pine	2940	367½	3
8	8	1	....	Oak	Oak	3360	420	4
8	8	1	Pitched	Pine	Pine	2940	367½	5
8	8	1	Pitched	Oak	Pine	4200	525	6
8	8	1	Pitched	Oak	Oak	3780	472½	7
8	4	2	....	Pine	Pine	2100	262½	8
8	4	2	......	Pine	Pine	3360	420	9
8	4	2	....	Oak	Pine	2940	367½	10
8	4	2	....	Oak	Oak	3780	472½	11
8	4	2	Pitched	Oak	Pine	4200	525	12
8	4	2	Pitched	Oak	Oak	5040	630	13
12	12	1	....	Pine	Pine	3780	315	14
12	12	1	....	Pine	Pine	4620	385	15
12	12	1	....	Oak	Pine	5040	420	16
12	12	1	....	Oak	Oak	5040	420	17
12	12	1	Pitched	Pine	Pine	6300	525	18
12	12	1	Pitched	Oak	Pine	8180	681⅔	19
12	12	1	Pitched	Oak	Oak	7980	665	20
12	6	2	....	Pine	Pine	4200	350	21
12	6	2	....	Pine	Pine	3780	315	22
12	6	2	....	Oak	Pine	3360	280	23
12	6	2	....	Oak	Oak	5460	455	24
12	6	2	Pitched	Pine	Pine	7140	595	25
12	6	2	Pitched	Oak	Pine	4620	385	26
12	6	2	Pitched	Oak	Oak	5040	420	27
16	16	1	....	Pine	Pine	4620	288¾	28
16	16	1	....	Oak	Pine	5460	341¼	29
16	16	1	....	Oak	Oak	5880	367½	30
16	16	1	Pitched	Oak	Pine	7980	498¾	31
16	16	1	Pitched	Oak	Oak	7980	498¾	32
16	8	2	....	Pine	Pine	5880	367½	33
16	8	2	....	Oak	Pine	5880	367½	34
16	8	2	....	Oak	Oak	7560	472½	35
16	8	2	Pitched	Oak	Pine	6300	393¾	36
16	8	2	Pitched	Oak	Oak	7980	498¾	37

Note.—When not marked pitched, the surfaces were rough and in the ordinary condition.

PORTABLE TRUSS-BRIDGE FOR MILITARY RAILROADS.

MATERIAL USED:—LUMBER.

For what Purpose.	No. of Pieces.	Length.	Size.	Contents B. M.	
Upper Chord	....	....	1″ × 12″	1,450 feet	
Lower "	....	....	1″ × 12″	1,500	
Blocks	4	9	12″ × 12″	432	Oak
"	4	5	12″ × 12″	240	
Abutment Shoe	4	3′–6″	12″ × 12″	168	
Ties	20	10.	2 × 8	267	
Braces, Main	8	6′–8″	4 × 5	89	
" "	8	6–4	4 × 5	84	
" "	8	5–11	4 × 5	79	
" "	8	5–8	4 × 5	75	
" Counter	4	6–9	4 × 5	45	
" "	4	6–7	4 × 5	44	
" "	4	6–3	4 × 5	42	
" "	4	6–2	4 × 5	41	
" Lateral	22	11–6	2 × 8	337	
" Sway	2	9–8	6 × 6	58	
" "	4	9–4	6 × 6	112	
" "	4	9–2	6 × 6	110	
" "	4	9–	6 × 6	108	
" "	4	8–6	6 × 6	102	
Brace Blocks	28	1	2 × 6	28	Oak
Floor Beams	30	10	8 × 9	1,800	

IRON.

For what Purpose.	No. of Pieces.	Length.	Size.	Weight.
Rods	4	6′–10″	1″ diam.	....
"	8	6–7	1″ "	....
"	8	6–2	1″ "	....
"	8	5–6	1″ "	....
"	8	4–6	1″ "	....
Bolts	8	3–10½	1″ "	....
"	8	3–5	1″ "	....
"	16	2–8½	1″ "	....
"	128	11½	½″ "	....
Washers, Cast iron	392	....	....	
Nails in Lower Chord	18,500	....	10d.	175 pounds.
" in Upper Chord	18,050	....	"	170 "
" in Lateral Braces	812	....	20d.	22 "
" in Sway Braces	182	....	"	13 "
Spikes in Lower Chord	336	....	6-inch.	61 "

The bridge was loaded with iron at the rate of one ton per lineal foot, after which a car loaded to weigh thirty tons was run to the centre, and the deflections noted as the weight was applied. The car was then removed and the deflections observed; it was again run upon the bridge, and left standing for thirteen hours; again removed, and finally all weight was taken off.

The wooden abutments sunk somewhat under the weight of the bridge and its load—from one inch to an

inch and a half, as was estimated—increasing the apparent deflection by that quantity.

At the end where the boards were notched into the block, as shown in Fig. 6, Pl. XII., no movement was perceptible; but where all extended to the end of the blocks, as in Fig. 7, the top chord appeared to slip along the block as the load was increased.

This slipping amounted to $\frac{3}{8}$ of an inch at its greatest extent, and remained permanent after the load was removed.

PORTABLE TRUSS-BRIDGE FOR MILITARY RAILROADS.

Tested April 17, 1863.

Total length, 60 feet. Clear Span, 54 feet. Depth of Truss at centre, 6 feet 4 inches, out to out. Camber of Upper Chord, 2 inches. Chords each 9 inches deep.

No. of Trial.	Weight applied.					Rods numbered in order from end. Deflections noted in inches.								
	Over Rod No. 3.	Over Rod No. 5.	Over Rod No. 7.	Total Weight.	Total Weight.	1	2	3	4	5	6	7	8	9
		Centre.		Pounds.	Tons. lbs.					C'tr				
1	21,000	....	21,000	42,000	21	⅛	⅜	⅞	⅞	1	⅛	⅛	⅜	⅛
2	42,000	....	42,000	84,000	42	1¼	1⅜	1⅞	2	2⅜	2⅜	2	1⅜	1⅝
3	54,180	....	54,180	108,360	54 360	1⅜	2¼	2⅝	2⅜	2⅞	2⅞	2⅜	2¼	1⅜
4	54,180	60,180	54,180	168,540	84 540	3⅞	5⅜	6	6¼	6¼	6	5⅛	4⅝	3
5	54,180	....	54,180	108,360	54 360	3⅜	4⅜	5⅝	5⅜	5¼	5¼	4⅞	3⅞	2⅞
6	54,180	60,180	54,180	168,540	84 540	3⅛	5⅝	6¼	6⅝	6⅜	6¼	5⅜	4⅛	3⅛
7	54,180	60,180	54,180	168,540	84 540	3⅞	6⅜	7¼	7⅛	7⅛	7⅜	6⅝	5⅜	3⅜
8	54,180	......	54,180	108,360	54 360½	3⅜	5⅜	6⅝	6¼	6¼	6⅞	5¼	4⅜	3¼
9	......	......	......	....	... .	2⅞	4¼	4⅞	4⅞	4¼	4⅛	4⅜	3⅜	2⅜

REMARKS.

1. 50 bars Railroad Iron, 420 lbs. each, loaded on each end. 100 bars in all.
2. 100 " " " " " " " " "
3. 129 " " " " " " " " "
4. Car loaded to weigh 60,180 lbs. run to centre of bridge.
5. Car removed from bridge.
6. Car again run to centre of bridge at 6 P. M.
7. After standing from 6 P. M. to 7 A. M., 13 hours.
8. Car removed from bridge.
9. All weight removed from bridge.

The greatest weight, 168,540 lbs., was 3121 lbs., or 1 ton 1121 lbs. per lineal foot.

EXPLANATION OF PLATES.

PLATE X.—*Board Suspension-Bridge.*

		Scale.
Fig.	1.—Side elevation	1 inch to 20 feet.
"	2.—Transverse section through centre	1 " to 4 "
"	3.—Mode of securing cable at end	1 " to 2 "

PLATE XI.—*Portable Arched Truss-Bridge.*

		Scale.
Fig.	1.—Side elevation of Truss-Bridge No. 1	1 inch to 20 feet.
"	2.—Transverse section at centre Truss Bridge No. 1	1 " to 2 "
"	3.— " " at end of blocks " No. 1	1 " to 2 "
"	4.—View of under side of lower chord, Bridge No. 2	1 " to 2 "
"	5.—Cross section " " " Bridge No. 2	1 " to 2 "

PLATE XII.—*Portable Truss-Bridge for Military Railroads.*

		Scale.
Fig.	1.—Side elevation of Truss	1 inch to 20 feet.
"	2.—Transverse section of Truss, at end of first panel	1 " to 4 "
"	3.— " " " " at centre	1 " to 4 "
"	4.—View of under side of lower chord	1 " to 2 "
"	5.—Cross section of lower chord	1 " to 2 "
"	6.—Side view of end chord	1 " to 2 "
"	7.— " " " " "	1 " to 2 "

PLATE XIII.—*Pier for Military Railroad Bridge.*

		Scale.
Fig.	1.—Side elevation	1 inch to 20 feet.
"	2.—End "	1 " to 20 "
"	3.—Plan	1 " to 20 "
"	4.—Top view	1 " to 20 "

Respectfully submitted,

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TRESTLE-BRIDGES FOR ORDINARY MILITARY ROADS.

THE plans and descriptions of military trestle-bridges which have been published heretofore are applicable only to localities and conditions, in which sawed lumber, good tools, and experienced workmen can be procured. These conditions usually involve a large amount of transportation. As every pound of weight carried unnecessarily is an impediment to the movements of an army, it has been the aim of the author to devise plans and expedients for bridges of every description that will avoid transportation, permit the use of any material that the country affords, dispense with carpenter and smith shops, fine tools and instructed mechanics, and afford the means of constructing bridges by the labor of common soldiers, with no other implement than the axe and auger.

The simplicity of these modes of construction forms a remarkable contrast to the elaborate plans usually adopted in Europe, and explains the reason of the surprise exhibited by distinguished European officers who visited Major-General McDowell, at Fredericksburg, while he was in command of the Army of the Rappahannock, at the extraordinary character of the military railroad structures on his line of communications.

It will appear, in reading the extracts from Sir Howard Douglass, that, to re-establish a communication across a broken arch near Dresden, the height of the roadway

being but 26 feet, "the Russians resorted to extensive and difficult applications of carpentry to repair this breach, which, being of considerable span, required a commensurate supply of large timber."

The bridge having been burnt on the retreat of the allies, the engineers under Napoleon undertook the task of reconstructing it. In reference to their plans, the following language is used: "Large trestles were first proposed, as the most expeditious and simple method of effecting this; but the project was rejected on account of the depth of the breach (26 feet), and consequently the great height which it would be necessary to give to trestles if laid in one story, and the difficulty and instability there might be in applying them in two tiers."

This extract shows the opinions entertained by European engineers as to the practicability of constructing trestles in more than one story, even for an ordinary road, and may account for the expressions of astonishment of "distinguished Europeans" at seeing the rules and principles of military engineering, as laid down in the books, so far violated as they have been in the Potomac Creek bridge, where trestles were erected in three stories on the tops of cribs 12 feet high, across an opening of 400 feet, and carrying a railway at an elevation of 80 feet, over which from 10 to 20 heavily loaded trains were passing daily. (*See frontispiece.*)

Trestle-Bridges.

The trestle-bridge figured in Pl. XIV., is supposed to be built of round sticks, cut from the woods. Most of the plans and descriptions are designed for this kind of material; for, if a structure can be built of round sticks,

with a flooring of poles, it will be much more easy to put it together of sawed lumber, if such can be procured. A plan which admits of the use of round, rough sticks is, therefore, much more useful than one which requires squared lumber. While nearly all works on bridges provide for the use of the sawed materials in construction, and give designs to which no other kind would be applicable, the aim of the author has been to go almost to the other extreme, and furnish designs for bridges and other structures adapted to the military service, which require the smallest possible quantity of previously manufactured material, and, as a consequence, the minimum amount of transportation.

The trestle in this plan has six legs, and forms a very stiff and strong support, adapted to any kind of bottom, whether level or otherwise. The two vertical legs on each side rest on a short sill, to which they are pinned by 2-inch pins. A horizontal piece pinned to the vertical legs supports the roadway, and two inclined legs serve the double purpose of supports and braces. They are driven into position and held by pins passing through the girder from above.

The projecting ends of the vertical posts, with a cap-piece pinned on top, form a good railing.

Manœuvres for Raising.—The plate represents two stout planks, one on each side, laid on the outside of the posts of the last trestle erected, and resting at the other end upon a float. Two pins driven through each plank, one on each side of the cap of the trestle, prevent it from slipping off, and a mark on the plank measures the distance. A trestle having been erected, the float is pushed out by means of the plank, until the pins at the end can

be dropped over the cap of the trestle just placed. The float is then put in line with a pole, and anchored by sliding down an anchoring post with a lever.

The trestle to be erected, having been previously floated to the place, is lifted by men on the raft, and placed in the position shown in the figure. A piece of board or pole being placed under the pin, to prevent the girder from slipping, the trestle is revolved without difficulty, placed vertically, the piece of board removed, and the legs pressed down to the bottom. The girder should then be at its proper level, which can be adjusted by a block, on the float on which the ends of the supporting plank rest. Pieces are then spiked across the legs, under the cap, to support it, the two outside stringers laid on and pinned, the planks and float moved forward for the next trestle, the braces put in and pinned, the remaining stringers or balks laid, and the roadway finished; the last operation being to cut the tops of the posts to a level, and put on the railing.

The girder might be fastened to the posts by a 2-inch pin passing entirely through; but the time required to bore the holes and drive the pins would be considerably greater than is required to spike on the pieces, particularly if the spikes be driven nearly through the cross-pieces before they are put in place. If the inequalities of the bottom are not great, and time presses, the pieces may be spiked on in advance, and the roadway adjusted to a level by means of blocks under the caps. This mode of construction affords unusually great facilities for adjustment in case of any unequal settling, as the low places may be raised by wedges driven under the ends of the girders.

Trestle-Bridges.

Pl. XV. represents another form of trestle-bridge. The trestle consists of only two legs, which should be of round sticks, about 8 inches in diameter. The caps which support the roadway are in pairs, across which two blocks are spiked into notches on the upper, and two more on the under side, as shown in the figure. The uses of these blocks are obvious. When the legs are drawn together by twisting the rope at the top, they are pinched between the blocks, and prevented from slipping, at the same time the brace pieces are spiked or pinned, which holds them in position.

This form of trestle is adapted to a hard and uneven bottom, to which it accommodates itself with great facility.

Manœuvres for Raising.—Put the trestle together; the rope twisted sufficiently to keep the legs from slipping, but no more; the end of the stick resting against the cap, to prevent the rope from untwisting; the length of the legs such, that, when resting on the bottom, the cap will be as nearly on a level as can be judged without measurement.

Float the trestle to its place; run out the two sliding-beams, which should be long enough to extend over two intervals. At the outside ends should be points, to keep the trestle from slipping, and, on the inside, a rope fastened around the cap of the second trestle, by twisting which, or by passing a rope beneath the cap, and allowing several men to pull upon it, the trestle can be raised.

Elevate the trestle, until the legs are in a vertical plane; then lower them to the bottom, keeping them vertical.

If the cap is now level, and at the proper height above the water, the rope can be tightened to pinch the blocks hard, and the braces spiked. But if the cap is too low, it can be raised, by striking on the lower side; and if too high, by slackening the rope, and striking the cap on the upper side, it can be lowered. When adjusted, the rope is tightened, the braces spiked, the rope removed, the stringers pinned, and the sliding-beams moved out for the next trestle.

Where a sufficient number of planks and boards can be procured, the most expeditious mode of constructing a trestle-bridge, and one of the best possible, will be found in the following description:

Make a number of floats from the balks and chesses, or the sticks and poles which are substituted for them. Form the trestles, by placing four legs parallel to each other, 5 feet apart. Spike a pole across, near the bottom, and another at the top; the length of the legs being of no consequence, provided they are long enough; they will be cut off to the proper length afterwards. These two poles will keep the legs in place.

A trestle having been set, as a, Pl. XVI., Fig. 1, tie the float B to it, while doing which, the trestle C is floated into such position, that the bottom of the legs will be towards the float, and pushed under it a greater or less distance, according to the depth of water, the distance being always less than the depth.

Spikes, S, are then driven into the outside legs, a rope,

t, passed around, to keep the trestle from slipping, and another rope tied to the pole on top, by means of which the trestle is raised with great ease, it being nearly balanced at the point S. Having been raised into a vertical position, it is dropped to the bottom, by slackening the rope t.

As soon as the trestle is dropped, without waiting to cap or brace it, another float must be instantly pushed in, tied, and the next trestle floated and raised in the same manner.

While this is being done, the trestle just raised must be capped; to facilitate which, the floats serve as platforms or scaffolds.

The cap is formed by nailing two boards opposite each other horizontally across the legs, the top edges in the same plane. (See details.) Braces are then spiked on the legs, care being taken to see that the posts are in line, and to move them, if they are not.

Next cut off the two inside posts, leaving the two outside ones for a railing. Spike a 2-inch plank over the tops of the posts, which should be wide enough to project over the boards. Thus a most excellent cap is formed. Lay the balks, spike them, untie and remove the float, and move it into position for another trestle.

The advantages of this plan are so numerous and great, that it should probably take precedence over all others for constructing trestle-bridges.

Some of these advantages are:

The work can be commenced in any number of places, at the same time; the only objection being, that there will be an irregular interval at closing, which is of little

consequence: if the interval is too long, put in another trestle; if too short, no matter.

No accurate soundings are required to determine the lengths of the trestles. The legs may be several feet too long; it is of no consequence; they are capped and cut to the proper lengths after they are in place.

The capping and bracing do not retard the work; it can be done by a different squad from that which erects the trestles.

The trestles can be put together near shore, and floated into place, a trestle and float being always ready to fall into position as soon as one is erected.

If boards and planks cannot be procured for caps, round sticks may be substituted. In this case, the two inside legs should be cut 5 or 6 inches above the horizontal poles, and two short pieces spiked across the poles, and against the outside legs, on which the ends of the cap-piece will rest. (See details.)

Pl. XVII., Fig. 1, represents a trestle which figures in works on military bridges as the Belgian trestle. It consists of two tripods, with movable cross-pieces supported upon pins. It has the merit of accommodating itself to inequalities of surface, but not to a greater extent than more simple forms that have been given. It is expensive, requires comparatively much time and labor in its construction, and its use is not to be recommended. It is given only as one of the forms that have been employed by engineers in Europe.

Pl. XVII., Fig. 2, is an illustration of the mode of construction of a trestle-bridge, of the form usually employed in Europe. It is supported on trestles, with four

legs, as shown in the figure. The manœuvre for placing the trestles is simple, and consists in supporting it on a pair of sliding-beams resting on a roller, by means of which it is pushed forward and dropped into place. The roadway is finished in the usual manner.

Pl. XVIII., Fig. 1, shows a mode of placing the ordinary European military trestle by a manœuvre of rotation. The ends of two sliding-beams are supported upon a float by pins. The trestle to be set is placed bottom upwards upon the beams, pushed out beyond the last trestle previously set, then rotated, pushed forward to the proper distance, then dropped, by pulling out the pins which support the beams upon the float. With care in balancing, one beam will be sufficient.

Pl. XVIII., Fig. 2, shows a plan for dividing a long span into two short ones, over which beams may be laid without trussing. The middle point is supported by a trestle resting on a pile of stones.

In Fig. 3, the middle point rests on a trestle, supported by a float; but, in this case, the floats should be stayed by ropes, to keep it from turning.

The following contribution to the book on military bridges is from Captain Paine, of the United States topographical engineers, an officer of great energy, experience, and practical ability:

HEAD-QUARTERS MAJOR-GENERAL HOOKER,
NEAR FALMOUTH, *February* 9, 1863.

General HAUPT:

DEAR SIR:—I will try to describe a rough trestle that is easily built where timber is plenty. (See Pl. XIX.) Select trees corresponding with the character of the

bridge to be built; after trimming them of their branches and boring two 3-inch holes to receive the bracing standards, a a, float them to the proper position, put in the standards, a a, turn the standards as far under as possible, and when one touches the bottom of the stream, it may be raised to its proper position by assistants on shore, having a rope attached to butt of the log at b. After the trestle, or horse, as I have been accustomed to call it, is raised, it is easy to find the length necessary to make the upright post *c*, which should be placed as shown, and lashed at the upper ends to the standards. A small stringer, d *d*, is next put on, that the ties *c c* may be level; these are securely pinned to their places when it is ready for the necessary stringers, which may easily be floated down and rolled to their proper positions.

I have found by experience that this kind of trestle, or horse, answers very well in quite a rapid current, where the small end, resting upon the bottom, seems to be pressed the harder upon the bottom, and is not very liable to be carried down stream.

This form will not answer for a deep stream or high trestle very well, but there are many places where it could be used to advantage.

The great advantage in this manner of constructing a bridge, is the fact that it is so easily constructed; the trestle is brought to its place without much trouble, while the trestle itself serves as a skid to roll up the stringers.

There may be nothing new in this mode of construction. If you have it already in your list, you may consider this as testimony in relation to its practicability, as I once built a small foot-bridge in this manner, and

am confident that it may be used to advantage in many places for heavier purposes.

Judgment should be used in regard to the fitness of the bridge for the place.

Yours, very truly,

W. H. PAINE, *Captain, A. D. C.*

To Brigadier-General H. HAUPT, in charge of R.R. Construction, etc., Washington, D. C.

Pile-Bridges.

A bridge on piles cannot, in general, be constructed as expeditiously as one on trestles; but where the bottom is liable to be undermined, or where the bridge is in danger from ice, trees, or other floating bodies, piles are much more reliable, are less easily carried away by floods or destroyed by an enemy, and, when partially destroyed by burning or cutting, are readily reconstructed.

Several simple and expeditious modes of constructing pile-bridges will be given.

Bridge of Piles—Constructed with Hand Pile-Drivers.—(Plate XX.)

The most expeditious mode possible of constructing a light pile-bridge for ordinary military purposes may be thus described:

The materials for the bridge having been collected, the balks and chesses of some of the intervals may be made into a number of floats. A rope is then stretched across the stream, a short distance above the proposed site of the bridge, and securely fastened. If the stream is wide, one or more buoys must be securely anchored

in the stream, to which the rope can be attached; by means of this rope the floats can be drawn into line.

The width of the float should always be equal to the interval between two rows of piles, so that, if placed against a row previously driven, a second row, driven on the opposite side, will leave the proper interval.

In preparing the piles, the heads should be accurately squared to a depth of about 1 foot, leaving a shoulder.

A platform is provided, which consists of two pieces of 2-inch plank, fastened together at right angles with a square opening at the intersection, fitting the heads of the piles.

The cross is placed over the head of the pile, and the pile placed by hand in position. It is there held vertically by two men; while four men mount to the top, by means of a small rope ladder suspended from the cross, where they ram the pile on the head with a rammer.

The rammer consists of a block of wood, with pins, 1½ inch in diameter, driven in the sides and top for holders.

The rammer-block may be about 1 foot in diameter, and 3 feet long.

The four men, placing their feet firmly on the planks which form the cross, and each holding the rammer by the handles, will raise and let it fall alternately on the head of the pile, the weight of the men greatly assisting in driving it home.

It will be seen, that by this plan of operation, a bridge over a wide stream might be commenced in twenty different places; in fact, whatever be the width of the stream, so many gangs could be set at work that no one gang would have more than two or three bays, or intervals, to construct, and the emulation which is excited between

the gangs of workmen, under such circumstances, would give extraordinary celerity to the movement.

If the bottom of the stream should be so hard that piles cannot be driven, trestles may be substituted, either with or without sills, as the character of the bottom may require.

Bridge of Piles, constructed with Hand-Engine.

Pl. XXI. represents a bridge of piles. The piles in this plan are three in a row, and are driven by an engine, which consists of a block of wood into which a hole is mortised, and a piece of plank passed through and pinned into it,—constituting, in fact, the handle of a large maul. The apparatus is supported on a float, on which a fulcrum is erected, and the handle of the maul held in position by a pin, the height being regulated by the holes, as shown in the figure. A rope attached to the end of the handle serves to operate the maul, to which, if necessary, four men can be applied.

The piles are held in place by timbers which project out, across the ends of which other pieces are laid, held in place by cleats.

The float is anchored by small piles, driven by hand. This arrangement is simple, but is not as expeditious as others that will be described.

EXPEDIENTS FOR CROSSING STREAMS.

Pile-Engines.

A VERY good pile-engine, capable of driving, at one time, the four piles of an ordinary bridge-trestle, may be made thus: Prepare a flat about 14 feet wide, and 2 or 3 feet longer than the distance between the extreme piles of a row. (Fig. 1., Pl. XXII.)

Place four planks edgeways across the bottom, the distances from centre to centre being equal to the distances from centre to centre of piles.

On each side of these planks, and at a distance of about 5 feet from the side of the boat, erect four pairs of 4 × 6 scantling, A B, vertically, pierced with pin-holes for 2-inch pins, at intervals of about 6 inches.

At the side of the flat nearest the upright, construct a drum, by cutting journals on the ends of a log 10 inches, more or less, in diameter.

Hammers are made by taking four blocks of wood, 1 foot in diameter and 3 feet long, C, through which holes are mortised, and handles, composed of plank, D, of the same size as those used in the bottom, are inserted, and secured by stout pins.

To steady the piles when driven, pieces of scantling, *e e*, are placed on each side, and a bar, *g*, across the ends, which hold the piles in place. The scantling, of which there are eight pieces, two to each pile, should not be

permanently pinned or bolted to the floor, but should slide in and out, as might be found convenient.

The upright pieces, *k*, are designed to steady the hammers in their descent.

The hammers are raised by means of four ropes passing over the drum of the windlass.

The ropes are connected with the hammers by means of an iron link passing over the ends, which slips off itself when the inclination is sufficient, and, after the hammer has fallen, is put in place by hand. A man stepping on the edge of the boat, and then on the windlass, can reach the ends of the hammers without difficulty.

It will be found convenient to allow the bars *e e* to project a distance sufficient to measure the bays or intervals between of piles with a cross-bar, to form a stop at the ends. With this arrangement, it will only be necessary, after a row of piles has been driven, to push the flat back, until the stop comes in contact with the piles, when an anchoring pile may be driven by hand to keep the flat from moving.

A very expeditious mode of anchoring the flat is represented at *m*, in Fig. 1. It is placed on the end or side of the boat opposite the piles, but not to interfere with the working of the windlass. It consists of a stout flat pile, say $3'' \times 8''$, to the lower end of which a shovel-shaped piece of iron may be attached if desired, to give it greater holding power. By pressing down the lever *l*, the pile is forced into the bottom and held. One of these anchor-piles, with the four piles to which the flat is attached on the opposite side, should give great steadiness; and when it becomes necessary to move the flat

to drive the next row of piles, the anchor is raised with the same facility with which it is lowered, and held securely in any position, by a pin passed through the holes.

After a row of piles has been driven, the most convenient way of sawing off the tops and putting on the caps, will be by the use of floats. The balks or chesses of a single bay or interval will suffice for a float; or a raft or float may be prepared in any other way. As fast as the piles are cut and capped, the balks and chesses can be laid, and the bridge finished; round sticks, 6 or 8 inches in diameter, being substituted for the balks, and straight poles for the chesses, when boards and scantling cannot be procured.

Truss-Bridges for Ordinary Roads.

The principles involved in military railroad bridges are also applicable to bridges for ordinary military roads; but in such structures lighter timbers and a smaller number of pieces may be used.

Most of the plans given will be adapted to round or flatted timber, and the use of such material as can usually be procured without resort to distant rail or wagon transportation.

Small Trussed Bridges for Roads.

Pl. XXIII., Fig. 1, represents a truss adapted to small spans. It consists of two sticks, A B, A C, placed in inclined positions, and lashed and pinned at A. Two pieces, *s s*, placed transversely, connect the two trusses,

on which two other pieces are laid in a direction parallel to the roadway. Across these, and parallel to *s s*, two other sticks, *n n*, are laid, and lashed to *s s* by ropes. The floor-beams rest on *n n*, and on the abutments, thus dividing the space into three intervals.

If the elevation of the cross-piece at *a* is not sufficient to permit cavalry to pass under it, it must be removed when the bridge is finished.

Diagonal braces, consisting of poles, should be spiked between the inclined timbers under the roadway.

Manœuvres for Raising.—Lay the sticks A B and C D on the abutments, the lower ends toward the opening, and projecting over a distance equal, or nearly equal, to the vertical distance between I and C. Lash the cross-pieces *s s* to both, and the cross-piece at A to one of the pairs of braces. Tie ropes to the projecting ends of the braces, and others to the tops.

Revolve the braces around the edges of the abutments at I and P, holding to the rope, to prevent the ends from slipping below the seats prepared for them at B and C.

Place the ends of the braces on the seats, and continue the rotation around B and C, until the ends meet at A against the cross-piece.

Tie the ropes to hold the braces in that position.

Lay pieces from the abutments to the cross-pieces *s s*.

Put *s s* in place.

Lay *n n* in the angles and lash to *s s*.

Place the floor-beams, finish the floor, and remove the manœuvre ropes.

Fig. 2, Pl. XXIII., the timbers are pushed forward

from the abutments a distance less than half the lengths of the sticks. They are loaded or tied at the back ends to prevent tilting; other pieces are placed on top, and the whole tied with ropes or pinned, and wedged as represented in the enlarged section.

Fig. 3, Pl. XXIII., represents a sketch of a longer span, in which the ends of the projecting timbers are supported by braces.

In this figure is represented a mode of tying to posts placed behind the abutments, which may often be used to advantage.

The truss represented in Fig. 3 may be extended to spans of 50 feet.

Small Bridges.

Pl. XVII., Fig. 3, represents a manœuvre for throwing a beam across an opening when the opposite side is not accessible. It consists in supporting the beam on, or near, the top of a vertical stick sufficiently stiff to bear its weight, and then pushing it forward until its end rests on the opposite edges of the opening.

The point of attachment is readily calculated for the height of the beam above the bottom, and the length of the stick from the side and hypothenuse of a right-angled triangle, from which the third side is readily determined.

Small Truss-Bridges.

Pl. XVI., Fig. 2, represents a form of truss adapted to spans of 60 to 70 feet. The construction is sufficiently exhibited in the sketch.

Manœuvres for Erecting.—Put the braces A, which should be in pairs, in contact with the girders B, at the proper point, connected by a pin.

Attach ropes to the braces A, and drop the heels in place, the braces being vertical.

Push forward B, holding it by means of a rope, and ease down into position.

Pin B to the anchoring pieces C, which are in pairs, and strengthen by spiking D behind it.

In the middle interval the girder is a single stick, and the truss-pieces are of planks, or poles, notched and spiked in pairs.

Each middle interval truss will weigh about 650 lbs., and can be raised into place by the direct efforts of eight men, four on each side, exerting a force of 80 lbs. each; or by means of a pulley, as shown in the figure, which, by changing the direction of the rope to a horizontal, will permit more men to haul upon it.

Pl. XVI., Fig. 3, represents a truss adapted to spans of 50 feet.

Manœuvres for Raising.—Place the trestles t t in position: the caps forming supports for the braces a a.

Lay the braces a a, which are in pairs, on the abutments, the heels towards the opening.

Bolt, or pin with wedged pins, the cross-pieces B at the proper places.

Revolve the braces until they are parallel to the faces of the abutments, and drop them into place, resting on the trestles.

Put in the girders c, and tie to cross-piece b.

Push out the girders c, holding back with ropes.

Raise up the straining beam d, from the bottom, by means of ropes, or slide it out, and, with the aid of ropes, drop it into place; the straining being notched, so that the top will project over a foot or more beyond the cross-piece; or, it may be made of two pieces bolted or pinned together with wedged pins.

Slack the ropes, and let B move forward until the straining-beam is compressed.

Pin, lash, and properly secure the pieces which intersect at B.

Complete the roadway in the usual manner.

Pl. XVI., Fig. 4, represents a truss adapted to small spans of about 30 feet.

In this plan, for the purpose of illustrating various modes of construction, the braces are supposed to be single, and to heel upon timbers suspended from the tops of the abutments; the connection being by means of notches and dowel-pins.

The horizontal timber is anchored at the back of the abutment, as shown in the figure.

Manœuvres for Raising.—Lay the braces upon the abutments, with the heels towards the opening.

On the lower side of the braces a c, pin the the cross timber b, with wedged pins.

Revolve a c until nearly vertical; tie the end of a plank on b.

Continue the revolution; slack the rope which holds a, and enter the dowel-pin.

Hold fast to the rope around b, and ease off gradually until a c is at the proper inclination.

Spike the plank k b, at k, which will hold A C firmly and afford communication with b.

Revolve the braces b d singly, enter them in the brace seats at d, and pin them to b.

Lower the cross-piece c, to d, throw ropes over each end and roll up to c.

Pin c to all the braces which it touches.

Place another cross-piece on top, at e.

Lash, pin, and otherwise secure the ends of these timbers, to prevent slipping.

Slide out the girders k e, by the aid of the plank resting on b, and draw over the girders from the opposite side by means of ropes.

Finish roadway in usual manner.

Pl. XXIV., Fig. 1, represents a truss adapted to spans of about 30 to 40 feet.

Manœuvres for Raising.—The bridge is put together on the bank. A roller, A, is placed on the edge of the abutment under each truss; another, B, attached to the end of the truss on the land side. It is then pushed forward, so as to project over the abutment a distance equal to one-half the span.

A trestle, C D, having its foot, C, at a distance from the opposite abutment equal to one-fourth the span, is leaned towards the approaching truss as it is pushed forward; and when the end of the truss is over it, the trestle is raised by means of the rope which carries the truss over the span, and lands it in position on the abutment.

Pl. XXIV., Fig. 2, represents a truss suited to spans of about 50 feet.

Manœuvres for Raising.—The bridge is constructed on the bank, as in the preceding case, and the manœuvres for throwing it across the opening are precisely similar.

Pl. XXIV., Fig. 3, is an isometrical view of a bridge trussed by planks or poles, put together at the bottom, raised entire at one side of the abutments by laying two poles, inclined as skids, and then sliding the trusses into place. The figure explains the manœuvre.

The plan of truss represented in Pl. XXV. is light, portable, and well adapted to localities in which boards can be conveniently procured.

The girder may be formed by drawing on the ground the arcs of circles, which form the two sides of the girder, and driving stakes around which the boards are bent and nailed securely. There should be one more board on the lower than on the upper side of the truss, and care should be taken that the joints are well broken.

The span may be 60 feet, and the depth of truss 6 feet; the width of the boards being 1 foot.

At intervals of about 5 feet, pieces of plank connect the two sides, and on the side of each plank, towards the middle of the truss, two rods of 1-inch iron are passed through.

If rods cannot be procured, ropes may be put around the outside and tightly twisted.

The ends should be well secured by bolts, as shown in the enlarged representation, the angle being filled with a block of wood of proper shape.

If bolts cannot be procured for the ends, iron hoops may be substituted. If hoops cannot be obtained, telegraph or other wire, tightly strained, may be wrapped around. If wire is not to be had, use rope: wrap it closely for 2 feet or more; drive it up the inclined sides, by means of blocks, and nail it, to prevent slipping. If nothing else can be found, use wooden pins, and wedge them at both ends.

To make a rigid truss, light diagonal braces should be inserted in the panels. If preferred, the top can be made straight instead of curved.

Manœuvres for Raising.—The design in the plate supposes that an opening of about 120 feet span is to be divided into parts, by means of a wooden pier, and two spans of 60 feet each thrown across without scaffolding.

The weight of one of the trusses will be less than two thousand pounds without braces, or with them about a gross ton, and is consequently very manageable.

The truss having been moved forward to the edge of the abutment, pieces of plank or board, about 4 feet long, are nailed across at A and B, to give a broader base, and prevent the truss from tilting over sideways during the manœuvres for raising.

Place a roller-block on the edge of the abutment, slide the truss forward, and place the end of two sticks, inclined like the letter A, under the truss at B.

Attach a rope to the rear end of the truss, and make fast to a tree, stump, or post.

Push the truss forward; it will roll easily, being supported at B, and resting on the roller at the edge of the abutment.

The trestle at A is in two separate parts, each consisting of two inclined legs, with a short piece of plank spiked on top of each pair for a cap. The trestle is finished when both trusses are in place, by connecting the two pairs of inclined legs, by means of the cross-pieces at top, bottom, and in the middle. The pier is not finished until the trusses on each side, supported by the four pairs of inclined legs, are in place, when the diagonals and ties shown in the plan are to be added.

When the end of the truss A has been advanced nearly two-thirds of the distance across, the pair of legs which supports it is leaned forward, and, catching the end of the truss, raises it, and carries it over to the position represented by the dotted lines, where it should be made fast by temporary bracing.

The trusses can readily be raised, and additional cap-pieces put on the trestles and wall-plates on the abutments, if required.

The opposite trusses of the two spans are connected by a piece of timber spiked on top.

If intermediate trusses are required, they can easily be rolled over by means of the outside ones, after they have been placed by the manœuvres just described.

The strength and durability of the trusses will be increased by coating the boards with pitch before they are put together.

The experiments previously described show the strength of such trusses. For railroad purposes, a larger number of boards must be used, and the top line should be straight.

The portable truss represented in Pl. XXV. is applicable to a great variety of structures, and to spans of considerable magnitude.

Pl. XXVI. illustrates an application of this truss to one interval of 180 feet, subdivided into three spans by wooden piers, and the trusses all placed in position without the use of false-works.

The *manœuvres for raising* are quite simple. The end trusses are put in position by the means illustrated in Pl. XXV., after which temporary braces of plank or boards are spiked to the trusses and to the trestles, to hold the end spans firmly until the middle one is in place.

To raise the middle trusses, the trestles which support it are first raised and leaned against those which support the end spans; shears are then erected on the ends of the trusses which have been put in place, and stayed by ropes, attached to any convenient point.

By means of a block and tackle, the middle trusses are then raised, one at a time, and put in place, which can be done without difficulty, as the weight at each end is only half a ton. The trusses must be hoisted a few inches higher than the positions they are to occupy permanently, when the trestles can be pushed out, and the trusses dropped upon them. The trestles are

then braced on all sides, and form the intermediate piers.

Fig. 2, Pl. XXVI., represents an application of the portable board trusses to a floating bridge. The spans of the bridge are finished complete at any convenient point, floated into position, anchored, and the trestles in two adjacent floats are then tied and braced, so as to act as one, arrangements being made to allow a sufficient degree of play to accommodate the rise and fall caused by the variable load at the points of junction of the spans.

By this arrangement, a bridge may be constructed at a point remote from that at which it is to be used, towed into position, and erected with great celerity.

A series of bridges may be constructed of different spans by the use of the portable board trusses, which can be erected without false-works, and will possess strength, simplicity, and beauty. If the trusses are composed of boards, both sides of which are well coated with pitch, there is no reason why such bridges should not be also very durable, and it is possible that, for ordinary road bridges, no better system can be devised. These bridges will be cheap and strong, and will admit of great rapidity of construction.

If the trusses are made of uniform dimensions, 60 feet long by 6 feet deep, the curves will form arcs of circles of 151⅓ feet radius. Trusses in single sets would be applicable to spans of 60 feet, or between abutments of about 56 feet. Two sets of these trusses, placed so that the ends would be in contact, and the upper sides lie in the same circle, would give a span of 118 feet and rise

of $11\frac{1}{2}$ feet; and if three are used, as in Pl. XXVII., the span would be $170\frac{3}{4}$ feet and rise of 26 feet. To construct a bridge as represented in Pl. XXVII., the abutments a and b must be formed at the proper distance apart, and capable of resisting effectually the thrust of the bridge. If masonry abutments cannot be built, crib abutments of logs, properly constructed and well braced, will answer very well.

Manœuvres for Raising.—The trusses next the abutments can be put in place by the manœuvres represented in the plate. The trusses being hauled or floated into convenient positions, the end b must first be raised, by means of a rope, to the level of the skew-back, and there fastened by attaching the rope to some fixed object, as a stake in the bank.

Another rope is attached to the end c, which passes over a pair of shears placed on the edges of the abutment and around a capstan.

By turning the capstan, the end c is readily raised to the proper elevation.

If the bridge is to be composed of four series of parallel trusses, it will be found most convenient to raise all four of the trusses of each end span at the same time; but if this cannot be done, in consequence of the large amount of rope which it would require, then the two outside ones should be raised, and connected temporarily by nailing a few boards across them.

The abutment trusses being in place, the ends c and d a few inches above the proper level, light shears are placed on the extremities of these trusses, as shown in the plate, and the middle ones raised.

The ends of the trusses at d and c are brought into contact by slacking the ropes around the capstan.

While still held by the ropes, additional boards, to the extent of two or more thicknesses, must be nailed over the tops of the trusses and continued to the abutment, so as to give an increase of resisting area at the abutment trusses, where the pressure is greatest, and, at the same time, furnish a neat and secure connection to the different series.

The outside trusses being placed, strengthened, and braced, there can be no difficulty in raising those inside, as a good scaffold has now been prepared to work upon. To complete the roadway, posts or trestles must be erected on the trusses, supporting a top chord of boards placed in horizontal layers. These boards should overlap each other where they come in contact with the arch, and be securely nailed to it. At the abutment, the boards are anchored to posts both in front and rear, so that they can resist a pushing or a pulling force.

By this anchoring arrangement, the points c and d will be prevented from rising or falling by the action of a variable load, and the structure will be rigid without the use of braces between the vertical posts in the direction of the longitudinal plane; but braces in a transverse direction should not be omitted.

Another very convenient mode of raising the trusses, which requires but a very small amount of rope, may be thus described:

Erect two trestles at each of the points c and d, the width of which must be less than the distance between the outside trusses, and the height greater than the elevation of the roadway. Spike cross-pieces on the

sides of these trestles, so as to form temporary wooden piers; the trusses can then be raised with great ease, either by means of levers or pulleys.

The outside trusses being secured, the piers can be removed, or they may be used in placing the intermediate trusses, as may be considered most convenient.

SUSPENSION-BRIDGES.

Rope-Bridges.

The rope-bridge across the Tagus, at Alcantara, was a remarkable structure; but it required a house in which to construct it, and after being put together, it was necessary to move it bodily. So much complication would appear to be unnecessary, and a mode of construction which requires no previous preparation is a desideratum.

The modes of construction about to be described leave nothing to be desired on the score of simplicity.

If the opening to be spanned by a rope-bridge has abutments on both sides, posts may be set vertically behind the abutments by digging a trench for that purpose. (Pl. XXVIII.)

Ropes are then taken, of sufficient length to reach twice across the opening, tied together at the ends, and the loops passed over the ends of the opposite pairs of posts.

The outside ropes should be of the same length exactly, and, when placed in position, a plank platform, with two men upon it, can be pulled by ropes to the middle of the span.

The intermediate ropes should be a little longer than

those on the outside, that, when looped over the posts, they will hang a few inches below the outside ones.

The men on the platform now put sticks through the loops of the ropes, and twist them until the slack is taken up, and they are adjusted to the lengths of the outside ropes.

The sticks being allowed to remain in, and resting against the adjacent ropes, will prevent them from untwisting.

The flooring can be put in place by pushing out the cross-pieces alternately, lashing poles across the ends, and bracing diagonally by means of ropes.

Stay-ropes should be attached to trees or posts on each side, to assist in preventing both the vertical and lateral vibrations.

Instead of the double ropes, adjusted in the middle, double or single ropes may be used, which are adjusted at the end. (Pl. XXVIII.)

This arrangement requires that two timbers, *c c*, should be placed behind the posts, between which the rope passes. Behind this pair of timbers is placed a piece of 3-inch plank, *d d*, in the middle of which is a hole 3 or 4 inches in diameter. The loop at the end of the rope is passed through this hole, and a stout stick or iron pin through the loop, by means of which the rope is twisted to any required extent.

Ropes for Passing Artillery and Wagons.

Artillery may be conveyed across streams of moderate extent by the use of ropes, the adjustment being at the ends. Several ropes are laid over trestles, and adjusted,

by twisting, to hang at the same level. The number and size of the ropes must, of course, be adapted to the weights to be carried.

To transport cannon or other heavy weights across the stream, a pair of wheels, with axle, may be used to advantage. The axle should be lagged to convert it into a drum, which will roll upon the rope platform: projections at the ends of the drum keeping it in place, as the flanges on a car-wheel.

A heavy beam is suspended from the wheels, by lashing ropes around the spokes and felloes. The drum is then drawn to one end, over a carriage, which contains the gun; the gun is lashed to the beam, the carriage drawn away, and the piece left suspended. The gun may then be pulled across by means of a rope winding around a capstan; or, the gun and carriage may be carried without taking them apart, if the ropes are sufficiently strong.

Bridge of Cables, Supported by Boats or Floats.

A serviceable bridge may in some cases be constructed by using cables, instead of balks or stringers, over the tops of boats, pontoons, or floats. The cables are attached to capstans on each side of the stream, lashed to the boats, and covered with the chesses or other roadway material. This mode of construction is not recommended as suitable for general use; but when only a few boats of large size are procurable, and the intervals would be too wide to be spanned by stringers of ordinary length, the cables offer some advantages; but the undulations would be considerable, and it would be diffi-

cult to attach stays. The best way of attaching them would probably be by eye-bolts screwed into the boats, near the surface of the water.

The suspension-bridge represented in Pl. XXIX., is supposed to be supported by cables made of boards.

The boards are nailed together in several thicknesses, laid horizontally, as shown in the details; the ends are spread apart, and wedge-shaped blocks inserted. The anchorage is obtained by several rows of posts, behind which horizontal timbers are notched and bolted, so as to prevent the fan-shaped ends of the cables from being drawn through. (See details, Pl. XXIX. Fig 3.)

To construct this bridge, no scaffolding is required; the boards are nailed together on the roadway at one end of the bridge, the surfaces, if practicable, being coated with pitch, so as to increase friction, exclude water, and promote durability.

Each cable, as it is put together, can be drawn across by ropes and capstans, and held back by ropes passing around trees or posts planted in the ground.

The lower blocks for the anchorage may be put in place and bolted, but the upper ones must be left out until the cable is in place, when they are driven in, the bolts inserted and tightly screwed.

The trestles which form the supports of the roadway are very easily placed, working from one or both ends of the bridge at the same time, and the braces may be either spiked or bolted.

After every thing else has been completed, a large number of spikes, sufficiently long to reach entirely through the whole series of boards which form the cable,

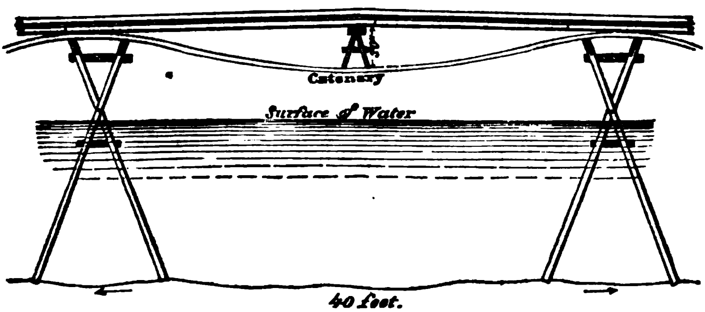
should be driven into it. Pins might be used, but spikes are far preferable, and much more easily inserted.

As represented in the plate, the anchorage is too near the face of the abutment, but it can be carried back to any distance without inconvenience.

A very cheap, efficient, and durable structure for ordinary road bridges may be constructed on this plan.

Military Board Suspension-Bridge, Supported on Trestles.

This bridge consists of principal trestles, 16 feet long and not exceeding 20 feet high, placed at intervals of 40 feet, over which are two flexible board suspension-beams, 14 feet apart, and hanging between the trestles in catenary curves, of about 2′–6″ versed-sines, upon which rest low trestles 3 feet high, dividing the spans



into lengths of 20 feet. Balks, 25 feet long, are laid with one end on the small trestle, and the other on the principal trestle resting upon both of the longitudinal planks uniting the crosses. These balks are covered with planks or poles, and racked down as usual in military bridges.

The principal trestles are formed of two St. Andrew's crosses united together at top by two longitudinal strips of plank, $16' \times 9'' \times 2''$, notched into them. Each cross is formed of two rough poles, 6″ to 8″ in diameter, bolted together, and braced by two strips of board, one nailed beneath the ends of the longitudinal strips, and the other as low down as can be reached. The small trestles are 15′–6″ long, made with a capsill and four short legs, as shown in the foregoing sketch.

The suspension-beams are each made of six 1-inch boards, a foot broad and 16 feet long, lapping by each other 2′–8″ to break-joints throughout the length of the beam, and fastened together by nails and spikes 4 inches apart, and by ½-inch bolts, in pairs, at intervals of a foot, passing through the whole six boards. The strength and durability of the beams are increased by coating the boards with pitch before putting them together.

The bridge is formed by first putting three boards together to form each of the suspension-beams, which are then pulled across the stream by means of ropes and capstans while floating on the water at their proper intervals of 14 feet apart, when the ends are well anchored to trees on the banks, piles of stones, logs well buried, or by any other simple expedients which will readily suggest themselves. By aid of boats the principal trestles are placed and the beams lifted upon them, when three more boards are added to form their entire thickness. The flooring is then laid in the usual manner and racked down.

EXPEDIENTS FOR CROSSING RIVERS.

Floating-Bridges.

Crib Pontoons.—To reduce the amount of transportation required for an army is a very important consideration. On long marches, through a country which affords little sustenance, it is sometimes difficult for horses to haul more than the amount of forage required for their own subsistence, and the transportation of bridge-trains, under such circumstances, becomes a most serious difficulty. It is very desirable, therefore, that expedients should be devised for constructing boats or floating bridges from materials that can be readily procured, during the march of the army. India-rubber blankets are extremely useful for a great variety of purposes, and may be used for the construction of pontoons; but old tents, or any kind of strong cloth, with a few boards, which may be procured from buildings in the absence of other sources of supply, will make very serviceable boats; and, with a properly drilled corps, a large number can be prepared in a few hours.

To construct a boat 18 feet long, 5 feet wide, and 2½ feet high, let stakes about 4 feet long, 2½ inches in diameter, and 2 feet apart, be driven in the ground, Pl. XXX., Fig. 1, to the depth of about 1 foot, so as to en-

close a space of the proper size for the top of the boat. The stakes should be so driven that the tops will be in the same horizontal plane, which is easily done by testing them with the edge of a board, and driving down those that are too high. Next: nail boards against the outside of the stakes, and extending four inches above the tops. Cross-pieces of the same diameter as the stakes are then laid across the tops, and pinned down upon them with strong wooden pins. Next: nail the side boards to the ends of the cross-pieces. Cover the bottom of the boat, which, in its inverted position, is now the top, with boards, and nail the projecting edges of the side boards to the bottom, securely. Then finish boarding the sides and ends to the proper depth.

The frame is now ready to be covered with canvas. For a boat of the dimensions proposed, the size of the canvas would be 23½ feet long and 10½ feet wide, about 6 inches being allowed for lap. The cloth may be put together, in any number of pieces, by daubing the edges of the seams with a water-proof composition, and connecting them with ordinary carpet-tacks.

The canvas having been prepared, it should be well coated on one side with a water-proof composition, composed of such materials as may be procurable: tallow alone, put on hot, if nothing better can be found. Then place the canvas on the frame, the coated side downwards; adjust it carefully, tack it thoroughly, and coat it thickly with hot composition. Spike or pin two or three stout poles longitudinally, to keep the bottom of the boat from abrading; and, to assist in launching, let these poles project 6 inches at each end. Loosen the stakes from the ground by means of levers; turn over the boat,

placing it bottom downwards; saw off the stakes about 2 inches below the top edge of the side and end boards, which have been previously brought to a common horizontal plane; pin stout poles on top of the stakes, on the four sides, and nail the side and end boards securely to them. The side poles should project 6 inches beyond the ends corresponding to those at the bottom, and lashed to the bottom poles by means of a loop of rope passed over the ends and twisted tightly by means of a stick. Lastly, the canvas is turned over the top poles, tacked down, and the boat is finished.

The bridge may be formed by laying round sticks for balks, at distances of about 2 feet, and using poles for chesses; the poles being kept in place by laying other poles longitudinally across the ends, and lashing them together. The balks should extend entirely across two adjacent pontoons, and be lashed together where they overlap. For anchors, any of the expedients described under that head may be employed.

If the country is wooded, and old boards and canvas can be procured, a bridge to any extent may be constructed in a few hours, capable of carrying an army, with all its artillery and supplies; and no part of the bridge equipage will require transportation, except the ropes and canvas.

If boards cannot otherwise be procured, they must be transported; and, in this connection, it is proper to state, that it would often effect great saving if a small portable saw-mill could be carried with an army. Mounted on broad wheels, its transportation would offer no greater difficulties than that of a piece of artillery; and, in a country sparsely populated, with timber of any

kind, but without saw-mills, it would prove of much value. It will be seen, in examining the expedients for constructing bridges, that rough boards play a very conspicuous part—in fact, are indispensable.

The boats can be used also for the ferriage of troops and supplies. They may be made of larger dimensions than those given; and instead of canvas, india-rubber blankets may be used to cover them.

Box Pontoons.—In localities where plank and boards can be conveniently procured, pontoons may be constructed very expeditiously, by placing ten partitions of 2-inch plank, each 5 feet long, and 2½ feet high, in parallel positions, on the top and sides of which boards are nailed: the box thus formed, to be covered with pitched canvas, as described in the mode of constructing crib pontoons. Where sawed lumber is at hand, the box pontoon will be more easily and expeditiously constructed than the crib pontoon; but if planks are not at hand, it may be preferable to use the poles or split timber than wait for it. To lose time in waiting for any material is the last thing that a military engineer should think of. If he cannot get what he wants, he should use what he has. For an army to wait a long time on the banks of a river for a pontoon train to enable it to cross, when time is important, indicates a country very barren of material, or a lack of resource in those whose duty it is to use it.

Wagon-body Pontoons.—Ordinary wagon-bodies, covered with pitched canvas or india-rubber blankets, may be used either as boats or pontoons. The small capacity of the wagon-body requires such pontoons to be placed more closely to compensate for it.

Wagon-bodies have been constructed of corrugated iron, with a view to use them as pontoons when necessary. They may sometimes prove useful. The wagons may be unloaded, the bodies used as boats to ferry troops across a stream, the cavalry horses compelled to swim, the artillery rafted, by lashing several bodies together, and flooring them with poles, the running parts of the wagons ferried over, and, lastly, the contents of the wagons carried in the same manner. An army, with all its artillery and baggage can, in this way, be thrown across a stream, without waiting for bridges, which can be constructed afterwards, to guard against the contingency of a hasty retreat.

Blanket-Boats.—(Pl. XXX., Fig. 6.)

In connection with the subject of boats and bridges, it is proper to describe a very simple, practical, and highly useful plan, for crossing streams by means of boats, constructed of a single rubber blanket, capable of carrying a soldier, knapsack, arms, and accoutrements, with only 4 inches of displacement. The size of some of the ordinary blankets is 6 feet long, and 4 feet 9 inches wide; but 7 feet by 5 feet would be preferable. If the height of the boat be made 1 foot, the length will be 4 feet, and the width 2 feet 9 inches, so as to be completely covered by the blanket. The frame may be made of round sticks, 1 inch and 1½ inch in diameter, in the following manner:

For the bottom, the two end-sticks are 2′ 9″ long, and the side-pieces 3′ 9″ long. They are connected by boring a ½-inch hole through the end-pieces, and into the ends of the side-pieces, into which pins are driven. The top

is formed in the same manner, and both top and bottom of 1⅛-inch sticks. The side-pieces of the bottom, and the top and bottom frames are connected by 1-inch round sticks inserted in ⅞-inch holes, in the same manner as the upright pieces are fastened in a chair. To keep the frame from falling apart, loops of cord are passed from top to bottom, and from side to side, and twisted with a stick. The rubber blanket is then spread upon the ground, the frame placed upon it, the sides and ends turned up and lashed to the top rail by twine passed through the eyelets. Two poles are placed longitudinally on the top, and two on the bottom, projecting over the ends about 3 inches. Loops of cord are passed over these projecting ends, and twisted with a stick, which binds the parts together.

One of these boats having a horizontal area of 11 square feet, would require 687 pounds to sink it 1 foot, and the average weight of a man would displace less than 4 inches.

In using these boats, it will be convenient to lash several together, side by side, upon which soldiers can be transported; the float can be paddled, or a rope may be stretched across, supported by floats, and the men can pull themselves across.

If used for cavalry, some of the men can hold the bridles of the horses, while the others can pull, paddle, or pole across the stream, the saddles being placed in the boats.

The frames are abandoned, or used for fuel, when the army has crossed over.*

* The frames might sometimes be filled with earth, and used as gabions to form a *tête du pont*.

Several of these boats lashed together, and covered with poles, would form a raft, on which wagons could be carried over; but for artillery, rafts of wagon-bodies, or something possessing greater powers of flotation, should be employed.

Where the timber is of large size, and round sticks for making the boat-frames cannot be procured, the material may be obtained, by splitting large straight-grained timber; and it is even preferable to the round sticks.

The Bill of Materials for the Frame of a Blanket-Boat is:

4 end pieces,	$1\frac{1}{2}$ inches	round or square,	2 ft. 9 in. long.
4 side "	$1\frac{1}{2}$ "	" "	3 ft. 9 in. "
30 uprights,	1 "	" "	1 ft. 0 in. "
10 pieces across bottom,	1 "	" "	2 ft. 9 in. "

8 double pins, $\frac{1}{2}$-inch diameter, ... 3 inches long.
4 pieces of cord or strong twine, each . . . . 9 feet long.
6 " " " " " . . . . 3 " "

1 india-rubber blanket, 6 feet long, 4 feet 9 inches wide,* with eyelets around all sides, not more than 6 inches apart.

30 feet of twine to lash the blanket to the frame.

Pocket Auger.—To aid in the construction of the frames, each workman should be furnished with a *pocket-auger*, which consists of an iron cylindrical case, 6 inches long, and marked with rings 1 inch apart, to serve as a measure.

The case contains an auger of $\frac{1}{2}$ inch in diameter. It is in two parts, screwed together in the middle, so that the auger can be taken out of the case and fixed in it at right angles, the case becoming the handle. In addition to this, a cutter is placed in one end of the case, which

* Blankets 8 feet by 5 feet would be much better than those of smaller size.

is used to cut a ½-inch tenon, on the ends of the upright, to fit the ½-inch holes in the top and bottom frames. An auger thus constructed would be an exceedingly useful tool for many purposes. It would be so small, that it could be carried conveniently in the pocket, and the principle could be applied to the larger sizes.

Ferry of Blanket-Boats.—A ferry may be made of blanket-boats in the following manner:

Rafts are formed by lashing together a number of boats, and covering them with boards, or poles, if boards cannot be procured. Twenty-five boats would make a raft 14 feet wide and 20 feet long, with power of flotation, at 6 inches immersion, of over 8,000 lbs.; fifty men could easily be carried in one of these rafts, with guns and knapsacks.

Two ropes are stretched across the river, and the men on the rafts pull themselves over rapidly, hand over hand, one rope being used for the loaded rafts, and the other to return the empty ones.

The rafts can follow each other in rapid succession, leaving intervals not exceeding the length of a raft.

The whole number of rafts should be three times as many as would make a train reaching entirely across the stream, with the proper intervals. This will allow a reserve sufficient to insure a constant stream going and returning.

If the stream should be 600 feet wide, the number of rafts would be forty-five; the number crossing at one time loaded would be fifteen. At a rate of movement of 2 miles per hour, the time required to cross would be about 4 minutes; and the number of men thrown across in one hour, would be about 10,000. The forty-five rafts would re-

quire 1,125 boats, which could be made by a single regiment of instructed engineer troops in an hour, if materials had been previously prepared.

One of these *blanket-boats* would weigh less than fifty pounds; a man could carry one for a distance of several miles without inconvenience; and, with the help of 1,000 feet of rope, a corps of ten thousand men could approach a stream, at a point where the enemy did not anticipate any attempt at crossing, and, in two hours, could be landed on the opposite side, ready for an advance, leaving a body of engineer troops to prepare for the possible contingency of a retreat, by constructing pontoon or trestle bridges, if necessary. Even in retreat, the rafts would afford great facilities for crossing, if covered by good batteries on the shore; but without bridges, it would be difficult to save the artillery.

Where surprises are to be attempted, such facilities for crossing large streams, without designating the point by previous preparations, would prove invaluable.

They might prove very useful in cavalry expeditions, to operate against the communications of an enemy.

If the material for the frames of the blanket-boats should be transported in wagons, they would, in that case, be prepared in advance, of dry lumber, and the materials for one frame would weigh but fifteen pounds. An ordinary wagon would carry material enough for two hundred boats.

The india-rubber pontoons of three cylinders are submerged by a weight of about 8,000 lbs.

Suppose blanket-boats are made of blankets, 5 feet wide by 7 feet long, and that the boats are 15 inches high, the length will be 4½ feet, and the breadth 2½ feet.

The number of superficial feet in the horizontal area will be 11¼. The displacement, with an immersion of 7½ inches, will be 7 cubic feet. The weight required to produce this displacement will be 437 lbs. Twenty boats would, with this immersion of 7½ inches, float 8,740 lbs., or more than a pontoon.

A raft of twenty boats, to be used as a substitute for a pontoon, would be 22½ feet long and 10 feet wide.

The thirty-four pontoons of an ordinary train would require 680 blanket-boats, as substitutes, and the material for the frames would require but four wagons.

If the flooring of the bridge should be hauled, about twelve wagons would be required for this purpose.

It is possible, that by the use of blanket-boats instead of pontoons, about half the transportation could be saved, but they would not answer in rough water.

They would possess the great advantage, that they could be carried by hand for miles, when the roads were impassable by wagons; 1,800 men could carry the flooring, with allowance of thirty pounds to each man.

Rafts of Casks.—(Pl. XXX., Figs. 4, 5; and Pl. LXI., Figs. 5, 6.)

The casks, of which the greatest numbers are used in the American army, are those which contain beef and pork. As the head must be removed to take out the contents, great numbers of these casks, perfectly sound and water-tight, but without a head, are thrown away, or, as is generally the case, used for fuel. If these casks were saved, and used for rafts, they would have great capacity for flotation, and a plan to use barrels without heads in such structures, is a desideratum.

The arrangement illustrated in Fig. 4 is designed to supply this want, and it is in fact much more simple and convenient to use barrels without heads than any others, requiring only a few nails and poles, and dispensing entirely with ropes, which are often difficult to be procured.

To make a raft of barrels, stand ten or twelve in a row, side by side, touching each other: nail four poles across the outside of the barrels, two at top, and two at bottom, the nails being driven from the inside into the poles, which, as the heads are out, can readily be done. Place another row of barrels, nail them to the poles of the first two, and attach two more poles, one at top, and one at bottom, to the second row of barrels; push the barrels thus connected into the water. If too many rows are connected on land, they will become too heavy to be readily moved. Any number of rows are attached in the same manner. When the raft is completed, the projecting ends of the poles on the outside are lashed together, and, at the points of contact of the barrels, a stout wrought nail should be driven through and clinched, thus forming a very perfect and stable raft.

The flooring, in the absence of sawed lumber, will be formed of round sticks, covered with poles or small bundles of twigs.

Power of Flotation.—Each cask contains 6¼ cubic feet interior capacity. Its displacement at the time of complete submersion would be considerably greater, as it would be measured by the exterior volume; but estimating only its interior capacity, its power of flotation would be 390 lbs.; and a safe load, in smooth water, would be at least 290 lbs.; a square raft of ten bar-

rels to a side, would carry 29,000 lbs. It is evident, therefore, that rafts of casks could carry as many men as could stand upon them; they could carry also artillery or wagons. They could be used for pontoons, for flying-bridges, for rope-ferries, and for various other purposes to which floats are applicable, even for floating wharves and lighters, by covering them with canvas to exclude water.

To move empty barrels to a considerable distance, a spike may be driven in the centre of the bottom, another in the top. A piece of board having first been nailed over the open end, slip a block of wood, with a hole in it, over each spike, and tie a string to the block, by means of which the barrel can be rolled to any distance on open ground.

FLOATING DOCKS, WAREHOUSES, AND TRANSPORTS.

IN connection with the subject of military bridges, some reference will be made to the means to be provided for landing supplies; and, also, a few suggestions as to their protection against injury, and security against capture.

Floats or arks may be constructed very cheaply, and of large capacity, and they could be made to play so important a part in military operations, that it appears to be necessary to give a detailed explanation of the mode of constructing one of them.

Assuming 60 feet long, 20 feet broad, and 6 feet deep, to be convenient dimensions for an ark, its mode of construction will now be described. (Plate XXXI.)

Scaffold.—To support the bottom while it is put together, a suitable place on the shore should be selected, where there is a gentle descent into the water. Posts, *p*, Fig. 1, Pl. XXXI., are then set in the ground, about 15 feet apart, capped with a timber, *c*, which runs in a direction parallel to the shore.

Another row of posts, q, is placed parallel to, and at a distance of 10 feet from, the first, and capped in similar manner.

These rows of posts are connected and stiffened by spiking braces upon the sides.

Cross-pieces, at intervals of 4 or 5 feet, are laid upon the caps and spiked fast.

Another row of very light posts is placed at *r*, 10 feet distant, on the other side of the posts, *p*. The posts, *r*, are not permanently fixed, but are movable around a pin at the bottom, so that they may be laid down, when they will form part of the inclined plane required for launching. On top of these posts rests a frame, m n, which turns on a hinge on the cap, c, so that the bottom of the float, when finished on the frame or platform, may be conveniently turned over.

To construct the bottom of the ark, lay five rows of 6-inch sticks, flatted on top and brought to a plane surface. At the joints they should lap for about 2 feet, and be pinned or spiked together.

Across these sticks, spike two 1-inch planks, and cut the edges to a line, giving a breadth on bottom of 20 feet: the plank laid so as to break joint.

Coat the plank with a composition, composed of tar, pitch, tallow, dried clay, or other ingredients, in proportions to be determined by experiment: the consistency being such that, at a temperature of 60 degrees, it can be dented with the finger. It should not be too hard to prevent perfect contact, or so soft that it would be rendered fluid by warm weather.

Take pieces of old tents, or other canvas, felt, carpet, or other material that can be procured; coat one side with the composition, applied hot; lay the coated side of the canvas against the coated side of the plank, and press down by running a small heavy roller over it. Coat the edges

of the first piece, and put on a second, lapping over 3 inches; and so proceed until the whole bottom is covered.

The canvas should project over the bottom about 1 foot all round, but the projecting portion should not, at that time, be coated.

Next, put a thick coating of composition over the whole surface of the canvas, and proceed, in the same manner as has been described, to lay a second thickness of canvas, coated on both sides, and so placed that the joints will not come over those of the first series. The edges of the second layer should project 2 feet beyond the bottom.

The top surface of the second layer of canvas having been well coated, inch boards are nailed over it longitudinally, or at right angles to the plank. The composition should be applied hot, and the boards nailed on immediately; the under surface of the board being also coated when it is applied.

By this means, it is believed that leakage will be impossible, if the work has been properly performed. The bottom boards should be nailed very thoroughly, particularly at the ends.

Turning Manœuvre.—The bottom of the ark being finished, it must be turned completely over. To accomplish this, the posts, *r*, are laid flat; the frame tilted into a vertical position around the hinge, and the revolution continued, holding the bottom from falling by means of ropes passing over pulleys with a turn around the sill, and eased off gradually, until the bottom of the float has been turned over on the launching ways. (Fig. 2.)

Rollers, *w*, are placed on the run-ways; they are

blocked, to keep them from turning until the float is ready to be launched.

To Build the Sides of the Ark.—The outside sticks are so placed as to be about 2 inches from the edge of the plank, and 3 inches from the edge of the boards. The sides are built up to the proper height by pinning on layers of flatted timbers; and to strengthen the sides, two partitions are placed in the length of the ark, also made of round sticks. The corners are connected as in a log-house, and a post is set in the corners and pinned to the legs which form the sides and ends. The inside is further strengthened by cross-pieces, at intervals of 4 feet, and posts placed on top of them and pinned to the sides.

The frame of flatted sticks being completed, the planking is put on vertically; then the canvas is turned up and tacked, after being coated inside and outside, as was done in forming the bottom. Lastly, the sides are boarded longitudinally, and the ark is ready for launching.

To launch the ark, it is only necessary to release the rollers, when it moves gently into the water, displacing but 8 inches when empty.

Uses to which the Arks may be Applied.

As Floating Wharves.—Floored over, and placed end to end, they form a communication 20 feet wide, on which tracks may be laid if desired. Side by side, they form a wharf 60 feet wide. The whole must be secured by anchoring piles.

As Warehouses.—Floored, and placed side by side,

they will form floating warehouses, of any desired capacity. (Pl. XXXII.) When used for this purpose, it may be convenient to make the ends to turn down, and support the roof by movable posts, that they may be set up or taken down at pleasure. The roof may be of canvas, painted. By covering the arks with the roof canvas, they may be towed from one port to another by sea; even if filled with water they could not sink.

As Lodging-houses for Laborers.—For this purpose they would have great capacity for accommodation. They could even be finished and furnished in good style for officers' quarters.

As Transports—They would save thousands of dollars per day, in the charter of vessels, for which they could sometimes be substituted.

For transportation on a line, part rail and part water communication, nothing could be better adapted. By placing four arks together, a platform would be formed, 40 feet wide and 120 feet long, holding four tracks, and each track four cars, in all sixteen cars, or a full train. By laying four tracks upon a floating wharf, all the cars could be run off in a few minutes, without once moving the float. By this arrangement, break of bulk, warehouses, accumulations of stores and buildings in localities where they would be liable to capture or destruction; the necessity of keeping an army of stevedores, and of building more wharves and increasing accommodations, as has been required for the Army of the Potomac at Acquia Creek, would all be avoided. In the supply of this army alone, the use of such a system would save to the government over $3,000 per day, and the work would be better done.

For Flying-Bridges or Ferries, the arks would be well adapted.

For Boat-Bridges, nothing could be more suitable. A very few, placed end to end, would span any ordinary stream. They could be anchored by piles, and the piles could support a railing.

For a Floating Bullet-proof Block-house.—Pl. XXXII., Figs. 3 and 4. Two arks can be connected together at the ends, by beams, having an open space of, say, 4 feet between the sides. The sides can then be built up of logs, pierced with loopholes for two ranks, one kneeling. The roof could be made of lighter timbers than the sides, but sufficient to prevent marksmen on trees or heights from firing into the vessel. If the sides were 8 inches thick, and the roof 4 inches, the weight would sink the vessel to the depth of 20 inches; with 600 men in addition, the draught would be 3 feet. The vessel would be poled from the inside; entered by means of a boat; and steered by a rudder or oar. For expeditions on rivers, in an enemy's country, they might be of much value. The same may be said in relation to the protection of property near streams.

For Floating Batteries against Artillery.—The logs could be thicker, faced with iron, pierced for cannon, and towed by placing a steamer between batteries on each side. If used as a local floating battery, it could be turned by hand, and might be useful as an auxiliary to the defence of river posts.

As Lighters.—As the draught of water, when empty, is only 8 inches, these floats could be used for lighters, especially for hay, cotton, and similar articles.

As Magazines for Ammunition—They could be anchored

at a distance from shore, safe from fire, and no danger to any thing else, if they should blow up.

In case of Retreat, instead of setting fire to the warehouses and burning the stores, the warehouses and stores, wharves and tracks, could all be towed to a place of safety.

SUGGESTIONS FOR THE PROTECTION OF MILITARY RAILROADS AND BRIDGES.

SOME suggestions as to the best manner of protecting military railroads and bridges will not be out of place.

The protection of a long line of railroad, penetrating a country where the inhabitants are hostile, and upon which an army, acting on the offensive, is dependent for its supplies, presents one of the most difficult problems that a general in the field can be called upon to solve; particularly, if opposed by an enemy possessing a force of enterprising cavalry.

It is a military maxim, that success is achieved by that party who can concentrate the greatest force at a given point; and if an army of 100,000 men should be distributed as guards along 100 miles of road, with a brigade at every bridge, a force of only two brigades could almost certainly break the communication by a sudden dash, and be off before their opponents could concentrate: provided no artificial defences were resorted to.

From this fact, it may be laid down as a military maxim, that no extensive line of railroad, running through a hostile country, can be effectually protected

by any force distributed along the line itself, unless, in addition thereto, artificial aids shall be resorted to.

Is it, then, possible to protect such a line of military railroad, and, if possible, how can it be done?

Such a line can only be protected by occupying advanced positions upon its flanks; and the precise plan which should be adopted, the force required, the disposition of the force, and the character of the artificial appliances which should be resorted to, will depend upon the topographical features of the country; the number, position, and activity of the enemy; the directions of streams and woods, and the more or less open character of the country.

Pl. XXXIII. will serve as an illustration.

Suppose a railroad starts from the shore of the ocean, or the banks of a river, at 1, and passes at some distance from, and along the valley of, a stream, crossing numerous tributaries, over which bridges have been constructed. On the right, at a distance of fifteen or twenty miles, is a ridge of hills, the general direction of which is parallel to the railroad. On the left, a stream, beyond which is an open country of woods, and cultivated fields; the whole intersected by woods, parallel and perpendicular to the general direction of the line of defence.

The first consideration will be, to determine how far upon the flanks it will be necessary to go, in order to secure defensible positions.

Suppose the stream from 6 to 2 is of such character as to be passable only at the road-crossing 7, 8, 9, 10. It is obvious that, unless the enemy can approach by water between 1 and 6, small forces at these points can protect the crossings, and thus render secure the whole

line of road, from 1 to 2, from an attack on that flank. It being supposed that operations are carried on in a hostile territory, the convenience of the inhabitants is not to be regarded; and fords should be obstructed and roads blocked by cutting trees and letting them fall across, entangling them as much as possible, and driving hooked stakes to prevent them from being pulled away. In addition to this, block-houses should be built at the fords, and at the principal roads intersecting, directly in the middle of the roads, so as to have a line of fire each way. All the timber around the block-houses should be cut away, and formed into abatis. These block-houses serve as shelters instead of tents, and enable a small force to hold a position against superior numbers.

The gaps in the ridge should be occupied, block-houses erected, and the roads obstructed. If the ridge is wooded, trees should be cut down along its whole extent, to make it impracticable for cavalry, and paths cleared out behind the obstructions, which cavalry could patrol, and give notice of any attempt to remove them.

Advanced patrols will also be necessary, reconnoitring for considerable distances beyond these outposts.

Where the streams are shallow, and fordable at numerous points, and the country open and cultivated, the difficulty of protecting a road becomes much greater. In this case, the practicable points of crossing streams should be made as few as possible, by hauling trees and placing them so that the sharpened branches will project over the streams, or, in some cases, by rails, poles, or logs, so near the bank as not to give cavalry a foothold.

When there are streams or ridges running nearly parallel to the railroad, and at any reasonable distances,

they will almost invariably be the natural obstacles most easily rendered defensible; but free use should also be made of block-houses and abatis; and, in addition thereto, the advanced patrols should not be forgotten.

The more important advanced stations should be connected with the railroad by means of the Beardslee telegraph, now used in the signal corps, an instrument which any soldier who can read can operate, and by means of which a force to meet an approaching enemy could be concentrated by rail, if they should succeed in passing the outposts.

If the enemy should be so strong as to compel the force guarding the outposts to retire, they should endeavor to do it in good order, obstructing the road and making resistance wherever practicable. As an auxiliary, a few shells, buried in the roads, and exploded from time to time by Beardslee's apparatus, would greatly embarrass the advance, and possibly cause the attempt to be relinquished.

But if all efforts prove unavailing, and the defenders of the outposts are compelled to retire to the railroad, it may be assumed that the bridges will be the important points of attack and defence. Track cannot be torn up without implements, which it is difficult to carry, and the rails are too heavy to be easily removed,* but a few

* This remark was true when this paragraph was written; since that time, impressed with the importance of discovering means of destroying the railroad communications of the enemy wherever accessible, even where there were no bridges, the writer devoted a week to experiments on the most expeditious and effectual manner of tearing up track and destroying rails. The result far exceeded his most sanguine expectations. He can now tear up, and so effectually destroy rails, that they can never be again used; ten men, with apparatus weighing only twenty-five pounds, in pieces none of which exceed seven pounds in weight, and which, in consequence, are very portable, can tear up and destroy 120 feet of track in one

minutes will suffice to destroy a bridge, and break a communication, which several weeks may be required to restore.

The defences of bridges, therefore, become of great importance. If there are in the vicinity of the bridges elevated points, commanding a view of the roads along which an enemy would approach, such points should be occupied, artillery mounted, block-houses erected, and the whole protected by palisades and abatis.

All the approaches to the bridge should be effectually obstructed, except where the outpost guard must enter in case of retreat to the block-houses; and this passage must be well defended. This is a position in which a few shells, planted along the approaches, could be cxploded with great advantage.

Block-houses should be so placed, that no part of the bridge, above, below, or on either side, would be screened from fire; that no enemy could approach to destroy it, without certain death.

It will often be practicable and highly desirable, to enclose a certain space around the bridge, and including the block-houses, with palisades. Where the line of palisades crosses the railroad, doors can be placed to open on the approach of a train; the inconvenience attending this arrangement will be a small consideration, when compared with the security it will afford.

hour; 440 men, 1 mile; and 2,200 men, 5 miles in the same time. The results of these experiments were communicated to Major-General Halleck, General-in-Chief of the Armies of the United States, in an official report, dated May 16, 1863, accompanied by photographs of all the operations. Copies of this report, and photographs, have been sent to all the generals commanding armies in the field, but as it would be inexpedient, at this time, to make the information public, a description of the process cannot now be given.

Palisades cannot, of course, be continued across the stream; but if the stream be deep, an enemy cannot enter except by floats, and a boom, well under fire, will prevent this.

If the stream is shallow, the same object may be attained by building *crib-work* on each bank, laying across a beam, trussed, if necessary, and hanging thereto a swinging gate, resting at its lower end upon the water, and rising and falling with it.

Such arrangements as have been described for protecting roads and bridges, in a country where the inhabitants are unfriendly, and cavalry raids frequent, are indispensable. Whatever labor they may cost, or force they may require, in no other way can an army advance securely to any considerable distance from its base, relying upon a railroad for supplies. The amount of force necessary to guard the communications must enter into the plan and calculations of the campaign, and without such guards no extensive movements, requiring time, should be attempted.*

The following orders were issued for guarding the military railroads of the Department of the Rappahannock, under Major-General McDowell:

"*June* 5, 1862.

"1. The force required for guards will vary with the numbers, position, and proximity of the enemy, and must be determined by the officer in command; but, in

* The number of men required to defend bridges might be reduced by using the revolving guns, several forms of which have been invented, and which, by simply turning a crank, are capable of giving 100 or more discharges per minute with accuracy of aim. One or more could be placed in each block-house, with a prospect of very satisfactory results.

general, a sufficient force for sentinels along the track will be twelve men to each mile.

"2. The posts of sentries should average about ¼ of a mile; so placed as to command, at all times, the best possible view of the road. Three sentries should be assigned to each post, so as to afford relief at intervals of two hours. At the end of each post a board should be placed, with the number of the post which it faces conspicuously marked thereon on each side.

"3. At intervals of half a mile, block-houses should be erected to afford shelter and protection to the sentries. These block-houses should be so located as to command the road both ways. Where two tangents are connected by a curve, good positions will often be found at the intersections of the tangents. Trees and bushes in the vicinity of the block-houses must be cleared away.

"4. Each post will be supplied with one red and one white flag, and an ordinary lantern; the lantern can be used for giving danger signals at night, by holding the red flag in front, and in contact with it. It will be the duty of each sentinel to walk over the whole length of his post, within ten minutes of the time when a train is due in either direction; stand at the end nearest the approaching train, and signal all right or otherwise, as the case may be.

"5. The signal of all right is made by displaying a white flag by day, or a white light by night; and for danger, or to stop a train, a red flag by day, or a red light by night.

"6. When the sentinels have been posted, a list shall be prepared, giving the names of sentries on each post, and the hours when on duty, which hours shall not be

changed without good reason, and all changes shall be reported. This list shall be furnished to the officer in command, and a copy shall be placed in the office of the superintendent of the road.

"If sentries are not found upon their posts when trains pass, or if they neglect to give the signal, the number of the post and the hour of passing it shall be reported to the superintendent, and by him to the commanding officer, who will send for the sentinel, ascertain the cause of failure, and take such action as the case may, in his judgment, require.

"7. At bridges, additional precautions must be taken; at least one block-house should be constructed at each bridge; and where the bridges are important, or much exposed, from two to four may be required. It will be the duty of the guards to watch the bridges in times of freshet, and prevent accumulation of drift, or, if carried away, to aid in their reconstruction.

"8. Block-houses will also be required at points where important roads lead to or cross the railroads; at such points pickets should be thrown forward, and cavalry scouts kept in advance. It will often be advisable to obstruct roads leading to the railroad, which are not required for use, in order that a smaller force may be sufficient to guard them.

"9. No train must be stopped, except at a station, for the accommodation of any individual, whatever his rank or position, without orders from the superintendent or chief of transportation.

"10. The attention of the guards should be directed to the following General Order of June 4, 1862, and a copy should be posted in each and every guard and

station house, and in all public places along the road. The order was as follows:

"'*Ordered*, That any and all persons who may be detected in placing obstructions upon the track, destroying bridges, or doing any act designed to throw off trains or break telegraphic communications on any of the military railroads in the Department of the Rappahannock, will be punished by death on the spot; and residents in the vicinity of the place where an accident may occur from such causes, will be held responsible in persons and property; they must not remain passive, and permit injury to be done; they must use vigilance to prevent it.'

"By order of Maj.-Gen. McDOWELL.

(Signed) "H. HAUPT, A. D. C.,

"*Chief of Construction and Transportation:*

"*Department of the Rappahannock.*"

SUGGESTIONS AS TO THE MOST EXPEDITIOUS MODE OF DESTROYING BRIDGES AND LOCOMOTIVE ENGINES.

A SIMPLE and expeditious mode of destroying bridges, and rendering locomotive engines useless to an enemy, is often a desideratum. Cavalry may penetrate far into an enemy's country, may reach bridges forming viaducts on important lines of communication, which it may be desirable to break effectually; or, in retreat, the destruction of a bridge may be essential to the safety of an army, and yet time may not be sufficient to gather combustibles, or they may not be accessible, or the fire may be extinguished, or the damage may be so slight as to be easily repaired.

What is required, is the means of certainly and effectually throwing down a bridge in a period of time not exceeding five minutes, and with apparatus so simple and portable, that it can be carried in the pocket or in saddle-bags.

These requirements are fulfilled by a torpedo, Pl. XXXIV., which consists simply of a short bolt of $\frac{7}{8}$-inch iron, 8 inches long, with head and nut; the head to be

2 inches in diameter, and about 1 inch thick; a washer of same size as the head must be placed under the nut at the other end, with a fuze-hole in it; between the washer and the head is a tin cylinder, 1¾ inches in diameter, open at both ends, which is filled with powder, and, when the washer and nut are put on, forms a case which encloses it. A coat of varnish should be applied, to exclude moisture.

In using this torpedo, a hole is bored in a timber, the torpedo, head downwards, is driven in by a stone or billet of wood, and the fuze ignited; the explosion blows the timber in pieces, and, if a main support, brings down the whole structure.

The time required is only that which is necessary to bore a hole with an auger. Ordinary cigar-lighters, which burn without flame, and cannot be blown out, are best for igniting the fuze, which should be about 2 feet long.

For portability, the auger should be short, say 13 inches, and the handle movable and of same length.*

The proper place at which to insert the torpedo is of much consequence. Most of the Virginia bridges are Howe trusses, without arches. In this kind of bridge the destruction of the main braces at one end, and on

* The last augers provided by the writer for expeditions from the Army of the Potomac are still more portable; they consist of nothing more than the auger itself, no handle being carried. The shank of the auger is cut off near the termination of the spiral, flattened and formed into a cylindrical ring, 1½ inch in diameter, and 1½ inch broad; when used, a round stick is put through this ring to form a handle.

The lower part of the auger is protected by a tin case, 3 inches long, open at one end; the other end closed with a cylindrical block of wood, 1 inch thick, into which the point of the auger is screwed. The wood protects the point, and keeps the case on the auger, to protect the cutting edges. The auger is of the ordinary kind used by carpenters and ship-builders, 2 inches in diameter, and cut down to 10 or 11 inches in length.

only one side of a span, will be sufficient to bring down the whole structure. There are usually but two main braces in each panel, and two torpedoes will suffice to throw down a span. Two men can bore the two holes at the same time, without interfering with each other. Cartridges containing a fulminate would be more portable, but they are not always conveniently procurable, and their use is attended with risk of explosion. Pl. XXXIV.

It is only necessary to operate at one side, and on one end of a bridge. If one side falls, the other side is pulled down with it.

If the structure contains an arch, two additional torpedoes will be required, but in this case it may be equally advantageous to operate upon the lower chord.

Experiments made at Alexandria proved that a timber placed in the position of a main brace, and similarly loaded, was shattered into many pieces, some of which were projected by the force of the explosion more than 100 feet.

To render Locomotives unfit for service, the most expeditious mode would be, to fire a cannon-ball through the boiler; this damage could not be repaired, without taking out all the flues.

The usual mode of disabling engines consists in burning the flues, by letting out the water, and making a fire in the fire-box; but this is generally done so imperfectly that the enemy soon gets them in running order.

Instruction for the Use of Torpedoes.

With a 2-inch auger, bore holes in the main braces at the point A. Pl. XXXIV., Figs. 1 and 2. Insert the torpedo and ignite the fuze. There are usually two braces in each panel; a torpedo should be placed in each; in igniting them, hold the ends of both fuzes together, and set fire to both at the same time.

To bring down a span of bridge it is only necessary to blow down the braces at one end, and on one side of the bridge; if one side is thrown down, the other side must follow. If the bridge contains an arch, an additional torpedo must be put in each arch, as in Fig. 2.

Friction cigar-lighters, which the wind cannot blow out, will be better than matches for igniting the fuzes.

The most vulnerable points of a bridge are usually the main braces in the end panels, A A; the arches C C, when the bridge contains them; and the lower chords D D. Do not mistake the counter-braces B B for the main braces A A. The destruction of the counter-braces will not bring down a bridge.

To prevent the torpedoes and matches from becoming wet, in swimming or fording streams, the torpedoes, including the fuze, should be well varnished, and the boxes containing the matches closed with paper pasted around them, and then dipped in pitch or varnish.

The following instructions for the transport and erection of the military wire suspension-bridge equipage, as used by the armies of the United States, is published with the permission of Quartermaster-General M. C. Meigs.

WIRE MILITARY SUSPENSION-BRIDGE,

OF 200 FEET SPAN; SINGLE TRACK, FIVE FEET EIGHT INCHES WIDE INSIDE; CALCULATED TO CARRY A LOAD OF THIRTY POUNDS PER SQUARE FOOT.

Bill of Materials.

Wire Rope.

8 suspension-ropes, 4 on each side, each 400 ft. in length, No. 12, diameter 1½ in., weight 3 lbs. per ft., shackled at each end . . .	9,600 lbs.
1,400 ft. No. 20 suspenders, double, ½ inch diameter, and weighing ½ lb. per foot . .	560 "
400 ft. of guy rope, No. 16, ⅞ inch diameter, weight 1¼ lb. per ft.	492 "
Wrapping wire, viz.: 150 lbs. No. 10 annealed, for temporarily suspending the floor joists, and 50 lbs. No. 14, for fastening the suspenders to their places on the wire ropes, and to nipper the ends of the suspenders,	200 "
Total	10,852 lbs.

Superstructure.

(See Fig. 1, Pl. XXXV.)

50 beams for joists, rough saplings, oak or pine, dressed off on one side, from 6 to 8 inches diameter, and 8 ft. long	4,000 lbs.

400 ft. of guard logs—say 12 in. diameter round, and dressed off on the bottom and one side	7,000 lbs.
Pine plank under the tracks, 2 × 10 inches, and from 16 to 20 ft. long each, amounting to 400 ft. in length in all	1,998 "
Oak plank under tracks (upper layer), 2 × 20 inches, and 16 to 20 ft. long each, amounting to 400 ft. length.	2,664 "
1,600 ft. of pine planking, 12 × 1½ inch .	7,200 "
100 bolts, ¾ inch diameter, 21 inches long, with head, nut, and washer, for bolting guard logs to joists. 30 bolts, ¾ inch diameter, 28 inches, with head, nut, and washer	660 "
3 kegs of 5-inch spikes. 2 kegs twelvepenny nails	500 "
Total	24,022 lbs.

Quantity of Materials to be Transported.

In case there are no saw-mills in the neighborhood of the bridge, the sawed stuff for the floor and track-plank would have to be hauled.

The weight to be hauled is as follows:

Weight of wire rope, including reels, say .	12,000 lbs.
Iron bolts, spikes, nails	1,160 "
Sawed stuff	11,862 "
Total	25,022 lbs.

Eight 4-horse teams, each carrying a little over 3,000

lbs., will transport these materials, and two wagons will carry the necessary tools, the portable forge, and blocks and tackle.

If the sawed stuff is obtained from a saw-mill on the spot, the quantity of transportation needed is six wagons.

Timber required for one Tower.

(See Pl. XXXV.)

4 posts, 12 × 15 inches, 20 feet 6 inches long, bolted or pinned together.
2 sills, 15 × 15 inches, and 28 feet long, bolted together.
1 tie-beam on top, 12 × 15 inches, and 16 feet long.
2 braces, 9 × 9 inches, and 18 feet long.
2 plank, bracing the posts, 4 × 12 inches, and 15 feet long.

Stone Anchorage (for one side).

(See left anchr., of Pl. XXXVI.)

8 bars, 1½ inch diameter, 4 feet long.
14 bars, 1⅛ inch diameter, 3 feet long.

Anchorage in Soft Ground.

(See right anchr., Pl. XXXVI.)

2 posts, 15 inches diameter, 20 feet long.
2 braces, 12 inches diameter, 16 feet long.
4 logs, 10 to 12 inches diameter, 28 feet long.
For the sheet piling in front of the transverse logs, take 6-inch logs, split in the middle, and 12 feet long.

Anchorage in Hard, Compact, Clayey Soil.

4 posts, 11 feet long, 12 to 15 inches diameter.
4 braces, 13 feet long, 12 inches diameter.

1 sill at foot of braces, 17 feet long, and 12 inches diameter.

1 tie log across posts, 17 feet long, and 12 inches diameter.

List of Tools and Machinery required for Putting up the Bridge.

4 nippers; 4 pliers; 2 hand-vices; 4 cold chisels; 4 hammers; 2 sledges; 1 dozen axes and helves; 2 cross-cut saws; 1 whip-saw; 2 sets of carpenter's tools; 4 1-inch augers (patent); 2 1½-inch augers; 4 broad axes; 2 adzes; 1 portable forge, with 1 barrel of coal; 1 complete set of blacksmith's tools, including a vice; a small stock of iron, viz.: 50 feet ¾-inch round iron, 1 bar of steel for pointing drills, 2 × ½ inch, 1 bar of 1¼-inch round iron, 12 feet long, for drills, 1 bar 1-inch round iron, 12 feet long, for small drills; 2 pairs of double blocks for ¾ and 1-inch hemp rope; 1 coil of ¾-inch rope; 1 coil of 1-inch rope; 1 coil of ½-inch rope; 6 long-handled shovels; 4 spades; 6 picks; 2 chalk-lines; 2 screw-wrenches; 1 tape-line; 1 mason's square; 1 foot rule; 2 crowbars; 1 keg of tar; 1 rope ladder; flat iron for wedges, say 1 bar, ¼ × 2 inches and 10 feet long; 8 bars, 1 foot long, 1½ inches diameter, to pass through ends of clevises; two Sibley tents for men; 3 camp-kettles and mess-pans; rations.

Directions for Putting up the Bridge.

Selection of a Site.

In selecting a site for a new bridge, choose a point where the river is narrow, and where the banks on both

sides afford safe anchorage. A rock anchorage is the best, and requires the least labor. Large trees growing near the river bank may frequently be used to support and to secure the cables; but for anchorage, next to trees, compact dry soil is best. Low, wet, marshy soil should be avoided, if possible. The banks on each side should be at about the same height above the water.

When the site is fixed by other circumstances, it is often difficult to obtain a good anchorage, and the best disposition must be made of which the locality will admit.

Towers.

For a span of 200 feet, a simple trestle, as shown in Fig. 3, Pl. XXXV., will suffice. The bottom sill consists of two logs, 28 feet long, say 12″ × 15″ each, squared on two sides, bolted together by ¾-inch bolts, or else tree-nailed; they are sunk into the ground their own depth, the earth being rammed tightly around them. Care must be taken not to place them too near the bank, lest the pressure should push away the intervening earth. Four holes, 6 inches deep and a foot long by 4 inches wide, are to be mortised out, 14 feet apart from centre to centre, for receiving the tenons of the posts. The posts consist each of two logs, say 12 inches diameter, dressed flat on the side where they touch, and pinned together in three places by wooden pins of 1½ inch diameter. The length of the posts for a 200-feet span should be 20 feet from the top to the end of the tenon. At the top a seat 12 inches deep is sawed out, to receive the tie-beam connecting the two pairs of posts. This tie-beam is 16 feet long; hewed on all sides to 12 inches square for a length of three feet from each end: a ¾-inch bolt 2½ feet

long runs through the posts across the tie-beam in its seat. To support the ropes, a rounded piece of oak is spiked to the tie-beam, with four 1½-inch grooves cut in it;   the grooves are 1½ inches deep, so as to allow a cleat to be spiked upon it, which will prevent the ropes from jumping out.

The posts and tie-beams are put together on the ground, and hoisted up by a double block and fall; if there is no tree convenient to which to attach the fall, a light pole, say 25 feet high, must be raised, and be supported by three guys, one running towards the river, the ends of the guys being well secured. Previous to raising the frame, a rope must be attached to the tie-beam, to prevent it from falling into the river; afterwards the tower may be temporarily braced until the suspension-cables are hoisted.

The side braces 8 × 8 inches are next put up and spiked fast, and then the cross planking is nailed on, at a height of 15 feet, which leaves room enough for any wagon to pass underneath.

Anchorage.

The suspension-cable should have the same inclination on the land side of the tower as on the water side. For a 200-feet span, with the ground level, the cable will enter the ground at about 50 feet back of the tower, Whenever the nature of the ground is such that the anchorage has to be made nearer than this, a tower of 4 posts, as shown in Pl. XXXVII., Fig. 2, must be put up.

Rock Anchorage.

(See Pl. XXXVI., left side.)

The ground is represented as gently rising; each rope is fastened to a separate pin 1½ inch in diameter, driven 3 feet deep into the rock, and projecting 1 foot above. The holes must be drilled at right angles to the direction of the rope, or with even a little more than a right angle, so as to provide for any slight bending which may take place. The first set of pins are 42 feet in rear of the posts, the other 10 feet farther to the rear; the pairs of pins are about 4 feet apart transversely, and the mean directions of the two sets of four cables are 4 feet farther apart than they were on top of the tower. Five feet in rear of each large pin, a pin of 1¼ inch diameter is driven in 2 feet deep; a light wire-rope lashing connects the top of the large pin, and that portion of the small pin where it enters the rock; it is tightened by being twisted. The clevises at the ends of the ropes are merely slipped over the pins; in case a rope is too long, and has to be bent around the pin, a rounded oak block must be put behind the pin, and the rope passed around it, as too short a turn breaks a wire cable.

Tree Anchorage.

Frequently trees stand near the bank in such a position, that they are either wholly or partially available for fastening the cables and also for supporting them; an example is shown in Pl. XXXVIII. The diagram explains itself; the tops of the trees should be cut off, to prevent shaking. A very large tree will support the strain of four ropes combined.

Anchorage in the Ground.

When the ground is hard and compact, or of a clayey nature, and not likely to get wet and soft, an anchorage as shown in Pl. XXXVII., Fig. 3, is the simplest.

Two slanting holes, 4 feet in diameter, are dug 10 feet deep, 18 feet apart, and about 45 feet in the rear of the tower. In each hole are sunk two posts about 14 feet long, and 12 inches diameter, and kept 6 inches apart. At the bottom of the posts small sticks are pinned across, and a larger one put in transversely, so as to catch a hold in the earth. Three feet below the surface, a log, hewed on one side, 12 inches in diameter, and say 20 feet long, is laid in front of the posts and bolted or pinned to them; each post is braced by a stick from 16 to 18 feet long, the feet of all these braces resting against a log of the same size as the one running across the front of the posts. If there is more length of rope than required, the ends are passed around the posts, twisted and tied, two around each post.

In case the ropes are just about long enough, with sockets at the ends, they are secured as shown in Pl. XXXVII., Fig. 1; a pin 1½ inch diameter, and 1 foot long, is passed through the end of the socket, the pin resting against the blocking, which is put under as required.

Anchorage in Ground which is Soft or full of Moisture, and lacking Cohesion.

(See right anchorage of Pl. XXXVI.)

This anchorage consists of two posts, each supported by a brace, and four logs running across the whole width of the anchorage, say 28 feet long. In front of these

logs a row of flat sheet piling is driven in, the piles consisting of flat stakes about 12 feet long. To construct this anchorage, a ditch 4 feet wide, 16 feet deep, and extending the whole width from 25 to 28 feet, is dug. The two transverse slanting holes are next dug, into each of which a post and its brace are put. The posts are put in 17 feet apart. A cross-piece is spiked to the bottom of the post, so as to receive the weight of earth above and prevent the post from lifting. The two lower logs are first put in, and the earth rammed down solid; before the next log is put in place, blocks, 1 foot high, are put on the lower log, giving sufficient space between the logs to pass the cables through. The last log having been rolled in, the earth is rammed tightly around them, and the sheet piling driven in in front. Next, the braces are put in, care being taken to have a broad bed for their feet to rest against. Sufficient space must be excavated behind the posts, to give room for passing the ropes around them, or for being secured by sockets.

A pair of posts on each side is better than a single post, as shown in the drawing.

Operation of Hoisting the Cables.

Previous to dragging the cables across the stream, a wire should be stretched over the towers, from anchorage to anchorage, so as to compare the actual length of rope required with that on hand. If there is an excess of rope, the easiest mode of fastening is to wrap the end around the post and twist it around the rope, as shown in Pl. XXXVII., Fig. 3, the end being tied with wire, to prevent slipping. If the rope is just long enough, the way to fasten it is shown in Pl. XXXVII.. Fig. 1.

To remove the rope from the reels, the latter may be either run along the ground, allowing the rope to unwind itself, or the reel may be mounted on a spindle which revolves as the rope is paid off; this method is preferable. The reels should be mounted near the anchorage.

A ½-inch hemp line is first taken across the stream by a boat, one end is fastened to the wire rope, while a dozen men, or a sufficient number of horses, pull at the other end. At a given signal, they commence to haul the rope across the river. In case the rope is run off too fast, or the spindle should jump out of its bearings, the waving of a flag will warn the party on the opposite side to cease hauling. A man watches the reel in the mean time, checking it by the friction of a plank, if it revolves too fast.

When the rope is nearly run off, only 20 or 30 feet remaining, the signal to cease hauling is given; the rope is temporarily made fast at the edge of the bank, the loose end is removed from the reel and attached to the anchorage; this being done, the party on the other side haul in the remaining slack, and fasten their end, temporarily. In this manner all the eight ropes are passed over, four from the upper, and four from the lower side; the inside ropes being fastened first.

In the next place the ropes are hoisted to their places on top of the tower, in regular order, commencing with the inside rope. They are first hoisted on that side of the river on which the reels were placed.

The means of hoisting are already at hand, because the pole by which the towers were raised is still standing, and the double block probably yet hanging. To make this pole more firm and secure, it must be lashed

to the tie-beam above. The lifting on this side will be very easy. The ropes are not yet fastened permanently in the towers. We next proceed to the other side of the stream, to attach the ropes there. A rope hitch is first made fast to the inside cable, about half way between the tower and anchorage, the block and fall hitched to it, one end of the tackle being fast to the post in the anchorage. Another block and fall is fastened to the pole by which the tower was raised. The inside rope is then hoisted and the end fastened to the anchorage; the blocks are now taken off to see if the rope hangs at the right height in the middle of the span; if not, it may be readily raised or lowered by the fall attached to the anchorage-post. To facilitate the rendering of the ropes on top of the towers, they should be kept greased at those points, and a man must be stationed there with a sledge, with which he strikes the timber occasionally, so as to enable the ropes to slip by small jerks at a time, and not pull over the tower.

To ascertain how high the rope is to hang in the middle of the span, the level of the roadway is marked on both of the towers, and 18 inches above that a level board is nailed; when sighting across the river to the other board, the rope should just touch the plane of sight passing over the tops of the boards. The ropes must hang in the middle of the span, as here shown, and must be hoisted in the order indicated:

$$\begin{array}{cccccccc} 4\,\mathrm{o} & & & \mathrm{o}\,1 & 1\,\mathrm{o} & & & \mathrm{o}\,4 \\ & \mathrm{o} & \mathrm{o} & & & \mathrm{o} & \mathrm{o} & \\ & 3 & 2 & & & 2 & 3 & \end{array}$$

When the suspenders are on, the ropes come together thus:

$$\begin{array}{cccc} 4 & \mathrm{o} & \mathrm{o} & 1 \\ & \mathrm{o} & \mathrm{o} & \\ & 3 & 2 & \end{array}$$

Ropes 2 and 3 should be on a level with the tops of the guide-boards.

A camber of 18 inches is necessary for cables made of twisted ropes for a 200-feet span. A full load will bring down the floor to a level by the time the ropes are done stretching and the anchorage has become settled.

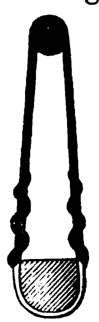
The anchorage must now be filled up, the earth rammed down hard, and ditches for drainage dug around.

Before closing the anchorage, the ropes must be well tarred.

Suspending the Joists.

At this stage the joists must be all on hand and ready for putting up; they are 8 feet long, 8 inches diameter, hewn off on one side, with a groove cut in 4 inches from each end to receive the suspender. Four of the joists to which the stays are fastened must be 10 feet long. The joists hang 4 feet apart; they will all be temporarily suspended by means of the No. 10 annealed wire, which is on hand for that purpose.

The work of suspending must commence on each side of the river at the same time, and proceed at an equal rate towards the middle. As each joist is hung up, a few light plank are laid, to enable the men to walk.



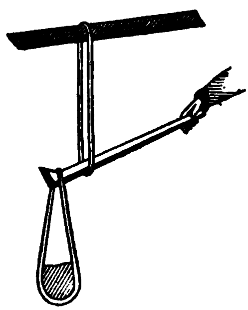
Each suspending wire takes a complete turn around the ropes, the two ends hanging down are passed around the joists as here shown, and twisted around.

At the middle of the span six joists should be tied close to the rope, touching it; this will prevent a hollow curve in the middle of the floor.

The joists, being thus hastily suspended, are

next regulated, so that the floor will hang in its proper curve. The floor should not form a straight line from the tower to the middle, but have a rise of about 6 inches at half that distance.

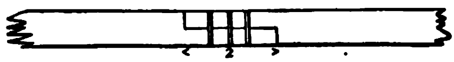
If it is necessary to shorten or lengthen a suspender, the joist is temporarily held up by two slings and a lever, as here shown; the upper sling hanging from the cable, and the shorter one passing around the end of the stick.



As soon as the floor is properly regulated, the operation of replacing the temporary wire suspenders by the permanent rope suspenders commences. The length of a wire suspender being fixed, it is taken off and a rope suspender is cut to the same length and put up, the beam being supported by the contrivance above shown. The suspender takes one complete turn around the cable, and then the two ends are fastened around the ends of the joists, twisted, and nippered with wire. It is also fastened to the cable by being tied with wire: small ladders being used in this operation.

The guard-logs are now brought on the bridge equally from each end. The inside face of the logs, which is hewn square, is 14 inches from the end of the joists, which at once determines their whole line along the bridge. As fast as they are brought on, holes 1 inch in diameter are bored through log and joist, and the two

are bolted fast; these guard-logs should extend some distance back of the tower, and be bolted to it, and also be secured in the ground. The logs are spliced as follows:



The splice is 2 feet long, and three wooden pins, 1 inch diameter, wedged at each end, secure it; the pins must be horizontal. The track plank are next laid down and spiked, and then the rest of the flooring. Care must be taken to break joint as much as possible both with the guard-logs and planking.

Stays.

There are 8 over-floor stays in all, two passing on the right and left side of each tower down to the floor; the shortest one connecting with the flooring at a distance of 8 panels out, the longer one extending 4 panels farther. The end of each stay is passed around the end of a joist, then twisted around itself and tied. The stay should form a straight line from the top of the tower to the floor, and must be tied to the suspender, to prevent sagging. The longer stay may be fastened at the other end directly to the post in the anchorage; the shorter stay is fastened to a small post of its own, as shown in the right anchorage of Pl. XXXVI. The stays must be hauled in and tightened from the land side.

Behind each joist to which a stay is fastened, a stick of 6 inches square must be wedged in between the two joists, so as to distribute the strain. The eighth and twelfth joists from each end out must be 10 feet long

each, to give a chance for fastening the stay. If any suspender rope is left, it should be used for under-floor stays, as shown in Pl. XXXVI.

Braces.

Whenever there is an opportunity, braces should be put under the floor, care being taken not to incline them too much; they must have a firm support underneath, and rest in the corner formed by the joist and guard-log. They must not be made so long as to render it necessary to raise the floor to get them under.

When the water is not too deep, and the bridge not too high above the water, a couple of posts may be put up to great advantage under the middle of the bridge, as shown in Pl. XXXVI. The posts should be lowered into the water from the bridge above; a couple of planks are then spiked to them immediately under the floor; these planks should be a few inches below the floor, and wedged in to support the floor. The upper ends of the posts must be sawed off below the tops of the joists, and the floor must not be spiked to them, so that, in case the posts are carried off by drift-wood, they will not carry the bridge along with them.

A light railing may be fastened to the suspenders, and also be put up in the middle of the span, to prevent the horses from shying at the water.

A sign-board must be put up at each end of the bridge, with this caution printed in large letters:

Walk quietly across this bridge, at the route step.

No marching in cadenced step, or to music, allowed.

Wire Rope Suspension-Bridge, of Two Spans, of 200 Feet each.—(See Pls. XXXIX. and XL.)

Pls. XXXIX. and XL. show the outlines of bridges of two spans, giving merely the different arrangements of the towers and anchorages. The construction of the floor is precisely the same as in the single span of 200 feet, before described; and the manner of hoisting the cables, attaching the suspenders, and suspending the floor, is also so similar, that any one who can put up the 200-feet bridge can put up one of two spans. The principal caution to be observed is to keep the two spans in equilibrium during the suspending of the floor; for instance, the parties suspending joists from the cables in Pl. XL., commence at each tower, and work towards the centre of each span at the same rate, so as to have both spans equally weighted at all times; the same rule must be observed in regard to the distribution of the plank and stringers when they are laid down. The eight ropes composing the two cables of Pl. XL., after being drawn across the stream, are first hoisted to their place on the centre tower, and then on the trestles on shore. In pulling across the wire ropes, care must be taken to have the middle of each rope as near as possible opposite the centre tower, in order to have equal length of rope on each side of the trestle. Wherever the cables consist of two, joined together by clevises and rings, the middle point is known. These connections must not rest directly on the cap on top of the tower, but to one side of it. The only job which is at all troublesome in the bridge of two spans is the raising of the frame of the centre

tower. Whenever the bridge is to be built on the site of one destroyed, having a centre pier of masonry remaining in good condition, towers are put up on the centre pier, of the same size and shape as on the abutments. This is shown in the form of a sketch in Pl. XLI. The spans are assumed at 175 feet, but may be extended to 215 feet, with the same strength of rope, viz.: four ropes in each cable.

As the raising of the centre tower of Pl. XL. is somewhat difficult, a full description of the operation is given.

Operation of Hoisting the Centre Trestle of Pl. XL.

The trestle consists in the main of two posts, connected at the top by a cap-piece. Each post is double, being composed of two sticks 50 feet long, and 15 inches to 18 inches in diameter; one side of each stick is dressed off, and the two are either bolted or pinned together. The whole frame is put together on shore (see Fig. 4), except the braces up and down stream.

If there is no flat-boat at hand of sufficient size, a raft must be made, say 20 feet wide by 25 feet long (see Figs. 2 and 3); the logs on the left side must be much heavier than on the right side, so as to have more lifting power there; the logs must be well secured by three sticks running across and pinned down. The frame is put on the raft, as shown in Fig. 2, 15 feet of the heavy end projecting over the edge. This distance of 15 feet is about right for a depth of water of 10 feet, which is assumed here.

Four sticks, 9 inches diameter, 15 feet long, and pointed, must be taken along; also, a number of crotches and poles for raising.

To get the raft over to its place, one of the wire ropes intended for cables is stretched across the stream and attached to each shore. This rope will hold the raft in its position in the middle of the stream.

Two pairs of piles are now driven in opposite the ends of the frame, and just in the centre of the stream, that point being determined by a small wire stretched across, having the centre marked on it. The raft is fastened to the piles just driven in, by ropes placed so as not to interfere. Two inch ropes are fastened to the cap at its centre, and lead to the shore; the one on the hauling side should be taken double; block and tackle are hitched to it on shore, the end block being made fast as high as possible. These preliminaries being arranged, the crew on the raft commence to raise the frame, the heavy end sinking into the water. As the end sinks the raft must be hauled in, so as to let the ends of the posts touch the piles at all times. As soon as the foot of the frame touches the ground in front of the piles, the party on the left shore commences to haul slowly, the men on the raft following up with the shores and props. The right guy must not be held too slack. When the frame is very nearly upright, the men on the left shore must haul very slowly, so as not to pull it out of the perpendicular. As soon as it is up, the up and down stream braces are put up, and the two ropes remain as guys. To hoist up the cable ropes, a small spar is previously lashed to the upper end of the frame, so as to project, say 5 feet above the cap. The blocks are attached to this spar (see Fig. 2). After the wire ropes are up, and temporarily fastened to the cap, the hemp rope guys may be removed.

Wire Rope Suspension-Bridge of Two Half Spans.

Pl. XXXIX. presents the case of a bridge of two half spans of 150 feet each, with a tower on the centre pier, but no towers on the abutments. The strain on the ropes is the same as in a full span of 300 feet, but in this instance the usual rope equipage of four No. 12 ropes in each cable, together with a full number of overhead stays, and under-floor braces wherever applicable, give an ample excess of strength. The calculation of the strain on the ropes is given further on.

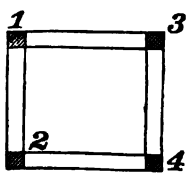
The principal advantage attained by two half spans is, that the labor and time of putting up towers on the abutments are saved; the cables, also, have to be hoisted on one tower only; and the strain of the ropes at the abutments being in a horizontal direction, allows of a somewhat better arrangement of anchorage, as shown in the right anchorage of Pl. XXXIX. If the wing walls of the old abutment are still standing, they afford an excellent support for the posts to which the ropes are attached; whereas, if there are towers on the abutments, the anchorage extends too far back to allow of any use being made of the resistance of the abutment. Lastly, there is not so much rope needed as for two full spans. The only thing requiring special directions is the raising of the wooden towers on the centre pier. Pl. XXXVII., Fig. 4, shows the details of the towers and their connection with each other.

Operations of Raising a Wooden Tower on a Pier in the Middle of the Stream.—(See Pls. XXXIX. and XXXVII., Fig. 4.)

Each tower consists of four posts resting on sills, and connected on top by caps. One stick on which the cables rest connects the top of the two towers.

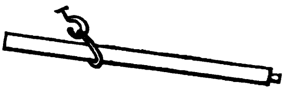
If no flat-boats are at hand, a log raft must be built, of about the same length as the pier, and say 25 feet wide. All the timber needed for the towers, having been prepared on shore, is put on the raft. To hoist the sticks up on

the pier, a pair of shears is required, consisting of two logs, each 32 feet long, 10 inches diameter at the butt, and 6 inches at top, connected by a sill below. The shear-sticks are hoisted up separately and put together on top of the pier, and are then elevated, partly by hand, assisted by poles, and finally by guy-ropes, which also hold them in position; the double blocks hang from the crotch; the shears are inclined forward over the end of the pier; the ends of the guys are fastened to pins temporarily driven into the masonry. The four sticks, composing the sills of the tower, are first raised, then put together, and put in their place; if the top of the masonry was not level, it should first be levelled off.



Next the four upright posts composing the tower are raised, in the order as here indicated: No. 1 log is hoisted first; the hitch of the double block is made fast at about one-third of the length of the log

from the end, as shown here; after being hoisted, it is placed in the mortise of the sill, and slightly



braced, so as to stand alone. No. 2 having been hoisted in the same way, the two braces are put in, connecting Nos. 1 and 2; the cap is also now put on Nos. 1 and 2. Nos. 3 and 4 are hoisted in the same manner, and are then connected with Nos. 1 and 2.

The other tower is raised in the same manner, the shears having first been moved to their proper position, by prying along the sill with handspikes, and easing the guys above. The second tower being hoisted, there is left the cross-stick to hoist, which connects the top of the two towers. The block-sling is attached almost to the middle of the log, so that it can be hoisted as high as possible; the shears stand almost upright, and as soon as the stick is hoisted or inclined over so as to allow one end of the stick to rest against the cap of one tower, the other end of the stick resting on the pier, the sling is then shifted to the lower end of the stick, which end is then hoisted up to its place on the other tower. The stick is thus raised up between the legs of the shears.

The shears must be left standing, in order to hoist the cables subsequently.

It is more difficult to obtain the same deflection of cable in each half span than it is in a single span, where there are guide-boards to go by. The general tendency will be to have the cables hang too slack; this must be guarded against; it is better to have them stretched too tight at first; they soon sink from stretching.

After the floor is suspended, it should have a camber of 15 inches in the middle of each half span. This is

obtained by putting up a horizontal guide-board on the pier, 30 inches above the floor; on the abutment no guide-board is needed. The line of sight passing from the guide-board on the tower to the top of the abutment will then touch the floor in the middle, if it has a camber of 15 inches.

In all half spans the tower should be made higher than in full spans of the same length as the half span; because the higher the tower, the less the strain on the rope. In Pl. XXXIX. the tower is 24 feet high; whereas, with towers on the abutments, their height would have been only 15 or 16 feet, which is at the usual rate of $\frac{1}{10}$th of the span.

Calculation of Strength of Rope required for the Bridge in Pl. XXXIX. *The Strain on the Cables is the same as in a full Span of* 300 *feet.*

Weight of bridge per foot, 170 lbs.	
Total weight of bridge = 170 lbs. × 150 ft. × 2 =	51,000
Max. load = 1,643 sq. ft. × lbs. = ...	49,290
Total weight	100,290
Tension arising from a deflect. of $\frac{1}{12}$th . .	1.65
Total tension on cables	165,478
With 8 ropes in the cables, the strain on each is	20,682
Or	10.34 tons.

The strength of a No. 12 rope is 30 tons, or three times the strain.

In addition, the stays support about one-fourth of the weight, which will give in all a strength of four times the strain, which is ample for a temporary bridge.

When rivers of considerable width are to be crossed, the different arrangements of two, three, or four full spans of say 200 feet, will suggest themselves; they are merely multiplications of Pl. XLI. Half spans are more seldom applicable.

PONTOON BRIDGE USED IN THE UNITED STATES MILITARY SERVICE,

AS DESCRIBED BY CAPTAIN DUANE, U. S. ENGINEERS.

The Modified French Bridge Equipage.

Pl. XLII. consists of 34 pontoon wagons, each loaded as follows, viz.:

7 long balks; 1 pontoon, inside of which are placed 12 balk lashings; 7 rack-lashings; 7 rack-sticks; 6 row-locks; 2 spring-lines; 5 oars; 2 boat-hooks; under the rear axle is lashed 1 anchor.

22 chess-wagons; load of each, 41 chess; 2 cables.

4 trestle-wagons; load of each, 2 trestle-caps; 4 legs; 4 shoes; 4 chains; 14 short, or claw-balks.

4 tool-wagons, loaded with carpenters' and intrenching tools, spare cordage, etc.; 2 travelling forges.

RECAPITULATION OF EQUIPAGE.

Pontoon wagons	34	Pumps	5
Chess "	22	Buckets	10
Trestle "	8	Pickets	24
Tool "	4	Rack-sticks	240
Forge "	2	" collars	48
Trestles complete	12	Cordage:	
Balks, long	238	Cables	44
" short (claw)	118	Spring-lines	128
Chess	902	Lashing-balks	720
Sills (abutment)	8	" side-rails	360
Rowlocks	200	Sheer-lines	2
Oars	192	Sets double blocks, large	6
Boat-hooks	100	" " " small	6
Scoops	70		

Discharge of Materials.

The pontoon is removed from the wagon by twenty men. The wagon is brought near the river bank, the pole towards the stream, and unlimbered. A double row of chess is laid from the carriage to the water. The lashings are removed, and the boat is allowed to slide gently into the water. The balks are piled on the left of the entrance to the bridge. Two balks are laid on the ground parallel, and 18 feet apart; on these is a layer of balks nearly in contact with each other, then two more directly over the first set; then a second course, etc., until the pile is about 5 feet high.

The chess are piled on the right of the bridge, as follows: three balks are laid on the ground parallel, and 5 feet apart; on these a course of ten chess not quite in contact; on these a second course of ten chess, etc., until the pile is 5 feet high. Other articles, as trestles, cables, etc., are in separate piles on the right of the chess.

CONSTRUCTION OF TRESTLE-BRIDGE OVER DRY RAVINE.—(Pl. XLV.)

Sections. No. of	Duty.	Non-Com. Officers.	Men.	
1st.	Abutment Section.	1	8	Construct abutments, etc.
2d.	Trestle-Carriers' "	1	8	Bring first trestle, then go for another.
3d.	" Builders' "	1	8	Erect the trestle, and adjust the balks upon the caps.
4th.	Balk Section.	1	10	Carry balks by right side to end of bridge; front men give ends to trestle builders; take rear ends, and assist in placing. Go back for more by left of bridges.
5th.	Chess "	1	24	22 carry chess, by right of bridge, to other two, who place them. Return by left.
6th.	Side-rails Section.	1	8	Bring side-rails, and lash them down.

Dismantled by reverse process.

The pontoniers are divided into detachments, in which each rank is numbered from the right, so that the front and rear rank men of each file have the same number.

The first section is composed of one non-commissioned officer and eight men, whose duty is to prepare a convenient entrance to and exit from the bridge, and to place the abutment sill.

For the latter purpose, there will be required picks, shovels, a maul, one sill, and pickets, the number and size depending on the nature of the soil.

A trench one foot in depth is excavated to receive the sill, which is placed in a direction exactly perpendicular to that of the bridge, and firmly fixed in position by pickets 8 inches from each end in front and rear; as soon as the balks are in place, a chess is arranged against their ends, its upper surface coinciding with that of the chess forming the roadway, and retained by pickets.

The approach to the bridge is then rendered easy, by cutting down and levelling the bank, if necessary; the abutment for the other extremity of the bridge is then arranged in the same manner.

Trestle-Carriers.

2d Section.—1 chief of section, and 8 men. Nos. 1 and 1 and Nos. 2 and 2 carry the cap, passing rack-sticks through the suspension-rings; Nos. 3 and 3, the legs and false legs; Nos. 4 and 4, the chains, shoes, and wedges. The section is then formed, and marched back to the trestle dépôt.

To Construct the Trestle.

3d Section.—1 C. S. and 8 men. No. 1 inserts the leg in the cap, and adjusts the chain; No. 2, the false leg

and wedge; No. 3, the shoe. No. 4 is stationed at the foot, to prevent it slipping.

The C. S. lays off the distance from the sill or last trestle, at which the new trestle is to be placed; he also measures the height the cap is to be above the ground, and from this estimates the distance the legs are to be thrust through the caps.

Nos. 1, 2, and 3 raise the trestle. No. 4 prevents the foot from slipping. Nos. 3 and 4 hold the trestle erect, whilst Nos. 1 and 2 adjust the balk, which they receive from the balk-carriers.

When the cap is so high that it cannot be reached from the ground, the manœuvre is performed as indicated in Pl. 45.

Balk-Carriers.

4th Section.—1 C. S. and 10 men. C. S. commands, "Lay hold," "raise," "shoulder," "forward;" each file seizes a balk, raises it; the front rank to the right, and the rear rank to the left shoulder. The section marches in line to the entrance of the bridge; the balk-carriers on each flank then precede the others, all keeping as close as possible to the right-hand side of the bridge; on arriving at the bridge-head they come into line; the front rank pass their end of the balks to the trestle section, step back and relieve the rear rank, and assist in placing the balks. The section is then formed in two ranks on the left side of the bridge, and marched off by the flank.

Chess.

5th Section.—1 C. S. and 24 men (22 carriers and 2 coverers): 22 carry chess; each man carries a chess

under the right arm, the forward end raised well up in the air; he marches on the right side of the bridge, delivers the chess to the coverers, then passes back to the pile of chess, by the left side of the bridge. The coverers stand on the balks to be covered (one on the 1st and 2d, the other on the 4th and 5th balks), facing to the rear; they receive the chess, and place them.

Side-Rails.

6th Section.—1 C. S. and 8 men. Nos. 1 and 1 carry side-rails for up-stream, Nos. 2 and 2 for down-stream side of bridge. They are carried in the same manner as balks, and are laid on each bay as soon as the coverers have left it. Nos. 3 and 3 lash up-stream, Nos. 4 and 4 down-stream rails.

The side-rails are placed immediately over the outer balks, and lashed by passing a rope around the balk and rail, tying it loosely, then twisting it up tight with a rack-stick; three lashings are placed on each rail.

Remarks.—The greatest attention should be given to placing the abutment. The stability of the bridge depends, in a great measure, on that of the abutment sill. When, after raising a trestle, the cap is found not to be on proper level, it is better to lower the trestle to the ground, to correct the error, than to attempt doing so whilst it is standing.

To Dismantle Bridge.

The sections remain the same as in the construction, operating in an inverse order: 6th section, remove the side-rails; 5th section, the chess; 4th section, the balks; 2d and 3d sections, overturn, dismember, and carry off the trestles; 1st section, remove the abutments.

CONSTRUCTION OF TRESTLE AND FRENCH PONTOON BRIDGE, BY SUCCESSIVE PONTOONS OVER WATER-COURSE.—(Pls. XLVI. and XLVII.)

No. of Sections.	Duty.	Non-Com. Officers.	Men.	
1st.	Abutment Section.	2	8	Construct first abutment; take materials for second across river, and construct it.
2d.	Trestle.	2	8	Construct raft of two pontoons; load it with separate trestles, caps, and legs, etc.; take raft to its place; put trestle together; right it; put claws of balks to caps; haul on cables; drop legs; disengage raft.
3d.	Up-Stream Anchor.	2	8	Two half-sections. Boats with up-stream anchors are above abutment; two half-sections enter two boats; row to place for anchor; cast it; drop boat to place in bridge, and go ashore for another boat. If boat is to be moored, down-stream anchor is also placed in stern.
4th.	Down-Stream Anchor.	2	8	Two half-sections. First with boat take anchor from boat already in bridge; drop down and cast it; second half-section bring pontoons with no anchors into bridge, and give them to balk-lashers.
5th.	Balk-Carriers.	1	10	Bring balks by right side of bridge; pass front end to trestle men, or pontoon lashers; men at front ends take rear ends, and assist in placing them for a pontoon; the balk-carriers push it off, and give their end to lashers: all go for more.
6th.	Balk-Lashers.	2	17	Four men, alternate by twos, in fixing spring-lines; two attend up-stream cable, one down-stream; in placing pontoon, ten (five in alternate pontoons) receive balks and lash them down.
7th.	Chess.	1	22	Twenty men bring chesses by right of bridge to other two, who face to rear, and place them.
8th.	Side-Rails.	1	8	Bring side-rails, and lash them down.

When more than seventeen boats are employed, the 3d and 4th sections should be doubled.

When the current is very rapid, the 3d section must be increased.

When the bridge is composed of twenty bays, or more,

there should be two sections for balks alternating; the same for the chess.

To Construct a Bridge over a Water-Course.—(Pl. XLVIII.)

The axis of the bridge should be, as nearly as possible, perpendicular to the direction of the current of the stream. This direction is determined by throwing a floating body into the stream where the current is the strongest; and as it floats down, mark (with two boat-hooks) a line as nearly perpendicular to this as can be determined by the eye. The wagons are unloaded, as has already been described; the pontoons launched.

At the command, "*Construct the bridge:*"

1st Section.—Construct the first abutment, as in the previous chapter; then embark in a pontoon, with the material for second abutment; pass over the river; determine its position, by sighting at the two boat-hooks marking the axis; construct this abutment and the road leading from it. If no trestles were used, they would plant pickets 30 paces above and below, and 3½ paces above, and 2½ below; the 1st for anchoring cables; the 2d for spring-lines.

2d Section.—Construct a raft (Pl. XLVIII.) with two pontoons (1), two balks (bb), lashed firmly to the gunwales; a deck is formed of chess (hh), covering part of first pontoon and the interval between the two.

The different members of the trestles are embarked: the caps and legs are laid alternately on the balks over the second pontoon, the chains on deck over the first, the false legs and shoes in the bow and stern of first pontoon; the raft is brought opposite the abutment.

The corresponding files in front and rear rank of the section have the same numbers. The rear rank performs the same operations for the down-stream part of the bridge that the front rank does for the up-stream side: No. 4 holds the raft in position by the guys or shore-lines, until they receive cables from the anchor detachment; Nos. 1 1 and 2 2 bring forward a sill, lay it on its side, the bottom towards shore; Nos. 1 1 introduce the legs in the mortises of the sill; Nos. 2 2, the false legs and chains; Nos. 3 3 place and secure the shoes.

The C. S. commands—"*Raise*;" the trestle is *righted;* Nos. 1 1 step on the trestle, and hold the legs, to keep them from sliding down; Nos. 2 2 adjust the ends of the balks, which are passed to them by balk-carriers; the raft is then pushed off by the balk-carriers pushing on the shore end of the balks, until the proper distance is attained.

The Nos. 4 4 are directed by the C. S. to haul or slacken their cables as circumstances may require, until the trestle is in its true position. Nos. 1 1 then thrust down the legs, pressing them firmly into the bottom of the river; Nos. 2 2 hook the chains; Nos. 3 3 drive in the wedges. C. S. commands—"*Disengage.*" All lift on the cap of the trestle just placed, in order to sink the pontoon sufficiently, to disengage the balk (*bb*) from under this cap.

3d Section is divided into two half-sections, for casting up-stream anchors. The pontoons which are to receive up-stream anchors are moored above the abutment. If the pontoon is to be anchored down stream, a second anchor and cable are placed in the stern. Each half-section embarks in a pontoon, with an anchor. The anchor

is placed in the bow, the flukes projecting over, the cable coiled immediately behind it. No. 1, front rank, attends the cable; No. 1, rear rank, steers; Nos 2 2 row. The line in which the anchors are to be cast is marked by two boat-hooks, placed about 20 paces apart, on shore. Arriving on this line, and opposite the position which the pontoon is to have in the bridge, the C. S. commands—"*Cast anchor.*" No. 1 throws over the anchor, and pays out the cable until the boat arrives at its place in the bridge; the cable is made fast, and the pontoon brought, with the boat-hook and oar, along the bridge-head; the short balks, supports, block and sill are arranged, and turned over to the cable detachment, the anchor detachment passing to the shore by the bridge after another pontoon.

The distance of the anchors above the bridge should be at least ten times the depth of the stream; otherwise, when a strain is brought on the cables, the anchors will trip.

In ordinary circumstances, an up-stream anchor is required for the alternate pontoons, and an anchor down-stream for every fourth pontoon.

When the river is not over 70 or 80 yards wide, or the current is gentle, a sheer-line may be used in place of anchors.

The sheer-line is a cable stretched across the river, 16 or 20 yards above the bridge, to which the pontoons are attached by lines. As the strain on this line is generally very great, the points of attachment on the shore must be secured with great care. An arrangement similar to the abutment sill may be used, or, if the soil is firm, an anchor buried in the ground.

4th Section; two half-sections.—First half-section cast down-stream anchor; half-section embark in a pontoon moved below the bridge, which has an anchor on it. No. 1 holds the two pontoons together, whilst Nos. 2 2 remove the anchor and cable to the anchor-boat, having previously made the end of the cable fast to the pontoon. The anchor-boat is then allowed to float down to the line of anchors, No. 1 paying out the cable. The anchor is then cast, and the boat hauled back to the bridge by means of the cable of the anchor just cast.

The boat proceeds to the next boat, having a down-stream anchor. Second half-section brings into line those pontoons which are not provided with anchors.

These pontoons are brought into their proper places, and held alongside the nearest pontoon between them and the bridge, until the cable-men are ready to take charge. The detachment then passes ashore by the bridge.

5th Section.—Balk-Carriers. Duty the same as 4th section, except that the front rank push off the pontoon before giving the balks to the balk-lashers.

6th Section.—Balk-Lashers. When the French train is used, an additional section is required to lash the balks to the gunwales of the pontoon.

This section is composed of two non-commissioned officers and seventeen men.

Four men alternate, two and two, in fixing the spring-lines, which connect the pontoons, bow and stern, and are made fast to the mooring-posts; three men at the cables—two for the up-stream, and one for the down-stream cable; ten balk-lashers. The five front-rank men enter the first pontoon, station themselves opposite

the lashing-hooks, facing down stream. They receive the ends of the balks from the balk-carriers, lay them in their places on the outer gunwale, and overlapping it by six inches. They then throw their weight on the balks, to keep them in place whilst the boat is being pushed off. In the mean while, the rear rank lash the shore ends of the balks to the abutment sill, if claw-balks are not used, and pass over into the second pontoon. When the second pontoon is pushed off, the lashers in the first pontoon receive the ends of the second set of balks from the carriers, place them on the gunwales of the pontoon in contact with the first set, and overlapping the inner gunwale six inches, lash them firmly to both gunwales, then pass over to the third pontoon.

7th Section.—Chess-carriers. The same as 5th section.

8th Section.—Side-rail carriers. The same as 6th section.

Dismantling Bridge over Water-Course.

8th Section.—Remove the side-rails.

7th Section.—Remove the chess.

6th Section.—Act on spring-lines and cast them off, tend cables, and unlash balks.

5th Section.—Remove the balks.

4th Section.—Two half-sections remove the pontoons without anchors; take up the down-stream anchors; the anchor-boat is brought up to the pontoon; sufficient cable is taken into the boat to allow it to drop down the stream to the line of anchors; the anchor is raised, and the anchor-boat hauled back to the bridge. This operation

is repeated until three anchors are weighed, when the anchor-boat returns to the shore. If the cable to the up-stream anchor is long enough, the readiest way is to allow the pontoon to drop down stream by this cable, coiling the down-stream cable until the pontoon arrives at the lower anchor-line; the anchor is then weighed, and the pontoon hauled by the up-stream cable to the upper line of anchors; when the upper anchor is weighed, the anchor-boat is then dispensed with.

3d Section.—Weigh the up-stream anchors, and take the boats to the second shore. The section is divided into two half-sections, which enter the first two pontoons. When the boat is anchored up stream, it is hauled up, to trip its anchor by its cable. Boats are taken to shore below bridge.

2d Section.—Take up trestles by the reverse of the process used in placing them.

1st Section.—Take up the abutments.

Construction of a Bridge by Parts.—(Pl. XLIX.)

The pontoons are composed of two or three pontoons.

If the velocity of the stream is less than two yards per second, they are constructed above the abutment; if greater, below.

The abutment and each bay is formed as in the case of successive pontoons, and at the same time. The parts are formed by sections of one C. S. and twelve men, each part as follows:—A pontoon is moored bow and stern to the shore; a second pontoon (No. 2) is brought alongside; chess are laid from the shore to No. 1 for the pontoniers to walk on; seven balks are brought;

five are placed as for an ordinary bridge, one on the bow and stern; No. 2 is pushed off; a third pontoon is brought alongside of No. 2, and is treated in the same manner.

The construction is indicated in the plate XLIX; *m m*, crossed spring-lines; *f f*, balks; *d d*, chess, to form the junction with the next part.

When the part is above the bridge, it is conducted to the line of up-stream anchors, drops its anchor, then floats down to its place in the bridge; a line is thrown to the bridge; it is hauled up to the head of the bridge; the balks are put in place, and the part pushed off; the chess and side-rails lashed. If the construction is from below, the part is towed to its place, where it receives one or two cables of up-stream anchors, as may be necessary, from another boat.

To Dismantle by Parts.

1st Section.—Take up the abutment from the shore of departure, and the balks, chess, etc., of the first bay, and pile the materials on the first part. The 2d section take up the balks, chess, etc., uniting the first and second parts, pile them on the second part, and the same for the other section; as soon as the parts are disconnected, the down-stream cables are attached to a buoy and cast adrift; each part is then hauled up by the up-stream oables, the upper anchors weighed, and the parts rowed or poled ashore and dismantled. If necessary, the up-stream anchors may be buoyed.

Construction by Rafts.—(Pl. L.)

Abutment is constructed as in the previous case, each part as follows:

No. 1 pontoon is brought up and moored bow and stern; chess are laid to it from shore. No. 2 pontoon brought alongside; five balks are laid resting on both gunwales of each pontoon, lashed and covered with chess; pontoon No. 3 brought alongside No. 2, and treated in the same manner; side-rails laid and lashed; cross spring-lines; two spare balks are carried on each part; the parts are conducted to their places as in previous case. The parts are united by lashing the adjacent pontoons bow and stern, and laying the spare balks over the joint formed by two adjacent side-rails, lashing these balks firmly, either with rope or rack collars. The extreme chess in each part should be nailed to the balks.

Dismantling.

The parts are disconnected by removing the lashings and balks that unite the different parts. The parts are then brought ashore and dismantled, as in the bridge constructed by parts.

Bridge by Conversion.—(Pl. LI.)

The position of the bridge having been determined, and the width of the stream accurately measured, a suitable place at some distance above the position of the abutment is selected for the construction of the bridge. The place of construction may be at a considerable distance from that which the bridge is to occupy, and is

frequently on some tributary of the stream to be bridged, out of sight of the enemy's shore.

The bridge is constructed parallel to the shore; side-rails are lashed on all except the extreme bays. The balks, chess, etc., for the abutment bay are embarked on the next to the last bay of the bridge; this contains, in addition to the articles necessary for constructing the abutment, two strong pickets. The up-stream anchors are deposited in the bows of the boats on the wheeling flank, ten or fifteen yards of the cables coiled, the remainder stretched along the bridge. Two strong lines are extended and lashed, the one over the bows, the other over the sterns of all the pontoons; these lines should be considerably longer than the bridge, and the ends coiled on the platform. The bridge is then allowed to float down to within fifteen yards of the first abutment.

The materials for the first abutment and bay are brought down in a pontoon; two strong pickets are planted at A and B to fasten the spring-lines, and one to fasten the line which is coiled on the next to the last pontoon.

The wheeling flank is pushed off; men are stationed in the bow and stern of each pontoon with oars and boat-hooks to increase or retard the progress of the pontoon, as may be necessary. A detachment is stationed at the first abutment to manœuvre the spring-lines; another to prevent the first pivot from touching shore; a turn of the shore-line is taken around the mooring-bar of the pontoon, and this line is eased off as the case may require. The anchors are cast as the pontoons in which they are carried come in the proper places, and their cables are brought to the pontoons to which they are

attached. The progress of the bridge is checked when it arrives opposite the abutments, which should be constructed during the conversion of the bridge, if the force is strong enough. The down-stream anchors are cast by the spare pontoons, as in the bridge of successive pontoons.

Dismantle by Conversion.

This manœuvre is rarely executed, except by an army in retreat, closely followed by the enemy.

The abutment bays are dismantled; the spring-lines are fastened to A and B; buoys are attached to the down-stream cables, which are cut off; the up-stream cables are lengthened out with spare cables. A strong line is passed from the next to the last pontoon to the shore. The bridge is allowed to swing around, the up-stream cables are eased off; also, the upper spring-line. When about half the wheel has been completed, the pontoons form such an angle with the current, that the tendency of the bridge is no longer toward the required direction, but to move obliquely toward the other shore. The strain on the lower spring-line is very great, and the shore-line must be used to haul in.

After the wheel has been effected, the bridge is floated down stream behind an island, or to some other place sheltered from the enemy's fire, and then dismantled.

Advance-Guard Bridge Equipage.—(Pl. LII.)

Consists of 29 pontoon wagons. Load of each: 7 claw-balks; 1 trestle complete; 1 canvas pontoon; 4 oars; 2 boat-hooks.

15 chess wagons: 41 chess, 12′ × 12″ × 1½″, 1 anchor and cable.

1 abutment: 4 abutment sills, 7 balks, 2 anchors and cables.

1 wagon: 1 sheer-line, 6 anchors and cables, spare cordage.

1 wagon: 7 anchors and cables, windlass, blocks and falls.

1 wagon: carpenter's tools and picks, shovels, etc.

The pontoons are of the Russian pattern (Pl. LII.), viz.: two side-frames, 21 feet long, and 2 feet 4 inches deep. These are connected by movable transoms. The whole made of 4-inch pine scantling.

To equip the pontoon, the transoms are inserted in the side-frames, and then firmly united by rack-lashings. A canvas cover is then stretched over the frame, and secured by lashings.

When employed in the bridge, the balks may be lashed to both gunwales, as in the French bridge, or the trestle-cap may be placed in the axis of the boat, with its upper surface 6 inches above the gunwales. It is supported in this position by two transoms let into the stanchions of the side-frames, about 5 feet from the bow and stern. The claw-balks rest on this cap, as in the Austrian bridge.

As the number of trestles in this train is equal to the number of boats, either of these classes of supports may be used to the exclusion of the other; in either case, forming a bridge about 200 yards in length.

CONSTRUCTION OF THE BRIDGE BY SUCCESSIVE PONTOONS, WHEN THE BALKS ARE NOT LASHED.

	N. C. Officers.	Men.	
1st.	2	8	ABUTMENT.—Construct the abutment, drive the shore line pickets, attach the shore-lines, embark with second abutment.
2d.	2	8	RAFT.—Construct a raft, embark trestles, caps, legs, etc. Construct trestles.
3d.	2	8	BOAT.—Up-stream, divided into half-sections, which alternate in bringing up-stream boats and casting anchors.
4th.	2	8	BOAT.—Down-stream; two half-sections: first half-section bring down-stream boats; second, cast down-stream anchors.
5th.	1	10	BALK-CARRIERS.—Bring the five balks for each bay.
6th.	1	22	CHESS-CARRIERS.—Twenty bring chess; two receive and place the chess.
7th.	1	8	SIDE-RAILS.—Two-half-sections; first, bring side-rails; second, lash side-rails.

When more than seventeen boats are employed, the third and fourth sections should be doubled.

When the current is very rapid, the third section must be increased.

When the bridge is composed of twenty bays or more, there should be two sections of balk-carriers, alternating. The same for the chess.

DESCRIPTION OF THE INDIA-RUBBER PONTOON BRIDGE.

BY GEN. GEO. W. CULLUM.

India-Rubber Pontoon Bridge.—(Pl. LIII.)

General Description.—The piers of the bridge are formed by anchoring *pontoons*, at intervals of 18 feet from centre to centre, and parallel to the current of the streams to be crossed. To the floating supports are secured *pontoon frames*, upon which rest the ends of the five *balks* of each bay; these ends being fastened to the middle pontoon planks of the frames, at intervals of 3′ 0¼″ from centre to centre. The ends of the balks, next both shores of the stream, rest upon wooden *abutments*, constructed on the banks. The covering of the bridge consists of *chesses* laid side by side upon the balks, which are secured in place by *side-rails*, laid on the chesses directly over the outer balks, to which they are fastened by *rack-lashings* passing through slits at the ends of the chesses. To clamp firmly the chesses between the side-rails and balks, *rack-sticks*, serving as levers, are used to twist up any slack there may be in the lashings, and are then fastened to the ends of the chesses by *rack-ties*.

Where the water, near the shore, is too shallow to float the pontoons, a *trestle, with a movable cap sill*, is substituted.

The roadway of the bridge is 11′ 8½″, between the

side-rails, which is sufficient for all ordinary purposes, but not enough for the passage of two pontoon wagons or field-pieces; but by placing the outer wheels of both carriages without the side-rails, the naves of the inner wheels will not interfere in passing each other.

Pontoons.

Description of Pontoons.—The pontoons are made of double india-rubber cloth, and consist each of three tangent cylinders, peaked at both extremities like the ends of a canoe, which are firmly united together, by two strong india-rubber ligaments, along their lines of contact, and widening into a connecting web towards the ends, in proportion as these diminish; the whole thus forming a single boat, 20 feet long and 5 feet broad, of great buoyancy and stability, and, from its form and lightness, presenting but trifling resistance to the water.

Each cylinder (including its peaked extremities) is 20 feet long, 20 inches in diameter, and is divided into three distinct air-tight compartments, each of which has its own *inflating nozzle.* The middle compartment occupies the whole width of the roadway of the bridge, but the ends of it are placed sufficiently within the ends of the chesses, to be secure from injury, especially from shot, except in rare cases. The end compartments are exposed, but, if pierced, can be readily repaired, as described elsewhere.

Still further strengthening the pontoon, are passed round the cylinders three wide bands, in which are formed six *side-loops,* three on each side. By passing a raft bar through them, two or more pontoons may be united into a raft. The bow and aft side-loops are also

used for attaching the pontoon-lashings, which secure the pontoon frame to the pontoon. Small loops are inserted in these bands, to which to lash the pontoon-planks, should there be no pontoon transoms. For this mode of attachment, four holes are made in the pontoon planks for each lashing. *Mooring-loops* are attached to each end of the three cylinders, in which to place the *mooring-bars*, connecting the mooring-cable with the pontoons.

Pontoon-Nozzles.—The pontoon-nozzles are made of brass. There are two parts—the *stopple* and the *tube*,—the former screwing into the latter, to open or close the nozzle. The tube consists of two cylinders of different diameters, but having the same axis. The stopple is a hollow cylinder, with four circular openings on the sides, for the ingress and egress of air, and is closed at the lower base by a flat cap a little larger than the diameter of the cylinder, so that the projection catches against a small side-screw to prevent its coming out, though, by removing the screw, the stopple can be taken out, if necessary. The stopple has a milled head, to facilitate screwing it in or out of the tube. On the interior shoulder of the tube, formed by the difference of diameters of its two cylindrical portions, is fixed a washer of soft leather, or gutta-percha, designed to make the nozzle perfectly air-tight, when the nozzle is screwed down.

Manufacture of Pontoons.—The pontoons are made of two thicknesses of strong, heavy cotton duck, coated with metallic rubber—the outer thickness being coated on both sides, and the inner thickness on its outer side only—making three rubber surfaces, or layers. In pre-

paring the caoutchouc gum for coating the duck, it is first cut up into small pieces and carefully washed, to rid it of all dirt and impurities, and is then passed between two grinders—in cylinders revolving with different velocities and heated by steam to about 150° Fahrenheit—and then mixed with white-lead and sulphur, in the proportion of 25 lbs. of gum to 10 lbs. of white-lead and 3 lbs. of sulphur. When the rubber becomes plastic, and is well mixed with the sulphur and white-lead, it is laid aside, and after a few days is again passed through a second series of revolving cylinders, more nearly in contact and heated like the first; and after it is made perfectly homogeneous, and about as soft as putty by this second grinding, it is passed through a third set of heated revolving cylinders—longer than the width of the duck to be coated. Upon one of these cylinders a thin sheet of rubber is formed, which is brought nearly in contact with another cylinder, over which the duck is passed from a drum around which it is wound. By the compressing power of these cylinders, the rubber is so forced into the meshes of the duck and firmly united with the surface, that it cannot afterwards, without difficulty, be removed. In like manner, several additional thin sheets of rubber are placed upon the cloth. The coating of the other side of the duck is similarly executed; and, if designed for the outside of the pontoon, a little coloring matter is added to the rubber to make it dark, the natural color of the gum being a light yellow.

The three compartments of each cylinder are first made separately, and of a single thickness of duck (except the ends of the middle one, which are double), coated on the outer side only. The middle compartment is

made of two pieces of rubber cloth (the width of the duck not being sufficient for the entire circumference), which are joined by laps of two inches. The two smaller compartments are made in the same manner, but with their cylindrical ends open. These ends are then slipped over those of the middle compartments so as to lap nine inches on the cylindrical part. The compartments being united, the three are covered by another thickness of duck, coated with rubber on both sides. This outer cover is made in two pieces—each of the length of the pontoon cylinder, and two inches wider than its semi-circumference, to allow for a two-inch lap. The three cylinders are then united to form a pontoon by strong ligaments of duck, coated on both sides, of five inches width, except near the ends, where they gradually widen out. The mooring-loops are next attached, and the three wide bands put around the cylinders.

Inflating nozzles—one opening into each compartment—are inserted in the pontoon. The end nozzles are securely seated in their places by several additional thicknesses of rubber cloth around them to insure the pontoons against air-leaks. The nozzles of the middle compartments are attached by a hose, about a foot long, to allow the nozzles to clear the cylinders when folded for packing, and thus prevent any chafing of the pontoons. Each nozzle is provided with an india-rubber cap, which can be removed at pleasure. Too much attention cannot be paid to making the seams as perfect as possible; for upon this depends, in a great measure, the perfection of the pontoons. A thorough adhesion *must* be secured at every lap, which requires that lapping surfaces be well coated with rubber, and that the seams

be strongly compressed with a roller, to force out all confined air. Should any air remain between the two thicknesses of the laps, of course there is no adhesion; and this air, when heated to the high temperature to which the pontoons are submitted in the last process of their manufacture, will expand, and cause a further separation of the lapping surfaces, and consequent air-leaks. The seams, after being well rolled, should have their edges well coated with a strip of pure metallic rubber.

After all the parts of the pontoon are put together, it is subjected to the process called *vulcanizing*, by which the whole character of the metallic rubber is changed. From a soft, sticky, unelastic, and soluble substance, it becomes firm, inadhesive, highly elastic, and insoluble in boiling water, or any ordinary solvents. The chemical changes which are produced by mixing the gum with white-lead and sulphur, and subjecting the compound to heat, are not yet clearly ascertained.

The *Vulcanizer* is a large hollow iron cylinder, like a steam-boiler, having a horizontal iron grating, of the length of the cylinder, which can be run in and out of it on a railway at pleasure. There is a steam supply-pipe, with a stop-cock at one end, and a waste-pipe at the other end of the vulcanizer. An attached thermometer, with its bulb with the cylinder, indicates the temperature within the vulcanizer.

The pontoon, having been first powdered over with flour or soapstone dust, is placed lengthwise on the grating, with cloths placed between its folds, to prevent them from adhering. The vulcanizer is then closed, the contained cold air let out, while the hot steam is let

in till it reaches 275° to 285° Fahrenheit, which requires about an hour. It is continued at that temperature for about an hour and a quarter longer, when the steam is let off, and the pontoon taken out and carefully examined to ascertain whether there are any imperfections, which, if they exist, are sure to be developed by this searching ordeal. The vulcanizing is a delicate operation, requiring care, judgment, and experience.

In cutting the rubber cloth for the pontoons, an allowance of a quarter of an inch per foot, in each dimension, should be made for the shrinkage which takes place in vulcanizing.

Repairs of Pontoons.—The greatest danger to which the india-rubber pontoons are exposed is that of being perforated by the musket-balls of an enemy opposing the passage of a river. Should a shot-hole be made in a pontoon, while forming the bridge, it may be temporarily stopped, without removing the pontoon from its place, by an india-rubber patch, a few of which the pontonier-sergeants should always have in their pockets. The patch is made of two circular pieces of india-rubber cloth—3″ in diameter—having a very small hole in the centre, through which passes a string of soft cord, knotted at one end, which will completely fill the hole. One of the circular pieces is crowded into the pontoon and drawn tight against the inside of it by the patch string, where it is kept in place by the inner pressure of the air, while the other circular piece is slipped on the string hard against the outside of the pontoon, and secured in place by tying a knot close to the outer surface of the patch. Larger holes could be stopped in a similar manner, but would, of course, require larger patches.

For the permanent repairs of small shot-holes, the torn edges should be trimmed off, making the opening of the inner thickness of the pontoon, say about an inch in diameter, while the outer thickness should be removed for a diameter of about 3 inches, and all the old gum (which, after being vulcanized, will not adhere to new) *carefully scraped off* from the outer surface of the inner thickness for the same diameter of three inches, and from the outer surface of the outer thickness, for a diameter of six inches. The hole being thus prepared, three or four coats of india-rubber cement, thinned, if necessary, with a little camphene, is put on the outside surface of the pontoon by the finger or brush for a width of about two inches around the hole—each coat of cement being dried in the shade before putting on the next. A patch of strong duck, 5″ in diameter, and coated on one side with cement, is then adjusted on the inside of the pontoon, so that the centre of the patch shall correspond to the centre of the hole; a second patch, 3″ in diameter, and coated with cement on both sides, fills the opening cut out of the outer thickness of the pontoon; and a third patch, 6″ in diameter, of vulcanized india-rubber cloth, coated on one side and cemented on the other, is put concentrically over all. Great care should be taken to coat well with cement the surfaces to be brought in contact, and to press them very hard to drive out any retained air, and thus secure a perfect adhesion. After completing the repairs, the pontoons are soonest fitted for use by exposing them, for a couple of hours, to the sun.

These repairs can readily be performed by the pontoniers; but it would be better, for permanent repairs, to

send the pontoons to a manufactory, that the patched part of the pontoon might be vulcanized.

Cement for Repairs.—To make rubber cement, cut some gum into small pieces (a common overshoe, if not made of vulcanized rubber, will answer), and dissolve it in camphene or pure spirits of turpentine, which, to hasten the solution, may be slightly warmed by a hot-water bath. A little sulphur, or finely pulverized charcoal, may with advantage be added to the dissolved gum.

Pontoon Bellows.

Inflating Bellows.—The bellows for inflating the pontoons does not differ, except in the formation of the nozzle, from that in ordinary use, and, therefore, requires no particular description.

Bellows-Nozzle.—The bellows-nozzle is of brass, and consists of three parts—the *nozzle-tube*, the *sliding-valve*, and the *nose-piece*. The interior surface of the nozzle-tube consists of a frustum of a cone (serving as a ferrule for the small end of the wooden parts of the bellows), and two cylinders of different diameters, all having a common axis. The nose-piece screws into the end of the nozzle-tube as far as its milled head, and is secured in place by a small side-screw. Its interior is a cylinder with open ends; the end entering the nozzle-tube having four semi-circular scallops, for the escape of air from the bellows, cut out of the side of the cylinder. The sliding-valve is a cylinder, perforated on the sides with two elliptical holes for the passage of air, with the upper end open, and the lower end closed by a cap of larger diameter than the cylinder. The valve has a free motion from the inner end of the nose-piece to the shoulder

(formed by the difference of the interior diameters of the cylinders of the nozzle-tube). Against this shoulder the projecting cap of the valve catches, thus preventing any air entering the bellows through the nozzle. In inflating the pontoon, the stopple of the pontoon-nozzle is unscrewed, and at the same time, by the same motion, screwed on to the end of the bellows-nozzle, thus opening the pontoon to the air from the bellows. When the pontoon is inflated, the stopple of the pontoon-nozzle is screwed up, thus closing the pontoon-nozzle and unscrewing it from the bellows.

Pontoon-Frame.

Description of Frame.—The pontoon-frame lies in the top of the pontoon, to which it is lashed, and serves as a means of attaching the balks to the pontoon and preventing their chafing it. The frame consists of three *pontoon-planks* laid longitudinally on the three cylinders, and two *pontoon-transoms*, which keep the pontoon-planks in place, by means of six *transom-lashings* and twelve *transom-cleats*. The whole frame is secured to the pontoon by four *pontoon-lashings*, passing through holes in the ends of the transoms and around blocks placed in the two fore-and-aft loops of the pontoon.

Pontoon-Planks.—The pontoon-planks are of white pine or spruce, 18′ long, 4½″ wide, and 1½″ thick. For fastening the balks and pontoon-transoms to them, copper staples are placed at the proper intervals, having grooves or channels under them, cut out of the planks, to admit of reeving the balk and transom-lashings through them.

Pontoon-Transoms.—The pontoon-transoms are of oak, 4′ 7″ long, 4½″ wide, and 1½″ thick, with six oak cleats

to each, screwed on the under side, and arranged in pairs, 4½″ in the clear, to embrace the pontoon-planks. On one edge of the transoms are three copper staples, their centres corresponding in position to the axis of the pontoon-planks, with grooves or channels cut out under them, through which the transom-lashings are reeved. Through each end of the transom are two small holes, for reeving the pontoon-lashings through.

Transom-Lashings.—The transom-lashings are of rope, half an inch in diameter, and 4′ 8″ long, having one end whipped and the other formed with an eye of the same cord, large enough for the free passage of the end of the lashing. To fasten a transom to a pontoon-plank, the whipped end of the lashing is passed through a transom-staple; then through a pontoon-plank staple on the left of the transom; then over the transom through the right-hand pontoon-plank staple; and, finally, over the transom, through the eye in the end of the lashing, and tied with a slip-knot.

Loop-Blocks.—The loop-blocks, used to prevent the pontoon-lashings from chafing the side-loops, are of oak. (Their form and dimensions are sufficiently indicated in the drawing). The projections or ears at the ends prevent the blocks slipping in the loops.

Pontoon-Lashings.—The pontoon-lashings are of rope, half an inch in diameter, and 4′ 8″ long, having one end whipped, and the other formed into an eye, as in the transom-lashings. To fasten the pontoon-frame to the pontoon, the whipped end of the pontoon-lashing, which is habitually reeved in the loop-block, is passed upward through one hole, and downward through the other hole in the end of the pontoon-transom, and,

finally, through the eye in the lashing, and tied with a slip-knot.

Mooring Equipments.

Manner of Mooring Pontoons.—The pontoons are moored by a light *anchor*, to which is attached one end of the *mooring-cable*, the other being fastened by means of a *rope-becket*, to a *mooring-bar*, passing through the becket and the three end loops of the pontoons. To mark the position of the anchor, a buoy is fastened to the anchor, by means of a *buoy-line* of the requisite length.

Mooring-Anchor.—The mooring-anchor is made entirely of iron, and weighs 45 lbs. Its parts are the *shank*, the *flukes*, and the *stock*. It differs in no respect from an ordinary kedge-anchor.

Box and Basket Anchors.—Should an anchor be lost, its place can be supplied with a box filled with stones, and having a cable, knotted at one end, passing through its axis; or by a basket-anchor made of a small gabion of the form of a truncated cone, with a straight stick, serving as a shank, passing through its axis and made fast to it. The ends of the gabion are each closed by four sticks, two being at right angles to the other two, forming by their intersections, a small square at the centre, just large enough for the passage of the shank, and leaving intervals between them for interlacing twigs to close the remaining openings. An anchor-ring is attached to one end of the shank, and an opening is left in the side of the basket or gabion for inserting stones or gravel.

Mooring-Cable.—The mooring-cable is of Manilla rope,

1″ in diameter, and 30 fathoms long. One end is fastened to the anchor-ring by a *mooring-knot*, and the other end to the mooring-becket by a *sheet-bend*.

Mooring-Becket.—The mooring-becket is of Manilla rope, 1″ degree in diameter, and three feet long, its two ends being spliced together.

Mooring-Bar.—The mooring-bar is a simple hickory stick, 4′ 6″ long and 2½ in diameter, with semi-spherical ends. It is slipped through the double of the mooring-becket, and through the three end loops of the pontoon, to distribute the strain of the mooring-cable equally on the three pontoon cylinders.

Mooring-Guys.—The mooring-guys are of Manilla rope, 1″ in diameter, and seven fathoms long. They are used instead of anchors for mooring the pontoons next the shores; one end being fastened to the mooring-becket and the other to strong *mooring-pickets*, driven firmly into the ground.

Mooring-Pickets.—The mooring-picket is a strong hickory stake, 4′ long and 3″ in diameter, having an iron band encircling one end, to prevent the head being split when driven by a heavy maul, and the other end being shod with iron, to make it enter the ground more easily, and protect the point.

Anchor-Buoy.—The anchor-buoy is made of two india-rubber cones, united by their bases, and having a ring at each vertex. It is 1′ 6″ long, and 9″ in diameter in the middle, and it has also a small inflating nozzle.

Buoy-Line.—The buoy-line is of Manilla rope, half an inch in diameter, and 3 fathoms long. One end is fastened by a *clove-hitch* around the flukes of the anchor,

and the other to one of the end-rings of the anchor-buoy.

Use of Pontoons.

Essential Requisites.—Military bridges should, if possible, have sufficient strength and stability for the safe passage over them, in the order of march, of infantry, cavalry, field artillery, and the wagons of the various trains accompanying an army in campaign. Siege artillery and infantry routed, being of great weight, special provision has usually to be made for their passage by lessening the bays of the bridge, or the substitution of rafts.

Strength of Bridges.

Strength of Balks.—The bridge being formed in the usual manner, with the pontoons 18 feet apart from axis to axis, the bearing of the balks, or distance between points of support, will be 14′ 3½″, or from axis to axis of inner pontoon-planks, 14′ 8″. Placing the pontoons at 14′ 8″ from axis to axis, the bearing of the balks will be 10′ 11½″, or 11′ 4″ from axis to axis of inner pontoon-planks.

The weight applied to the middle of a beam, supported at both ends, which will break it, is determined by the formula:

$$W = \frac{B \times D^2}{L} c$$

W being the breaking weight, in pounds; B, the breadth of the beam, in inches; D, the depth, in inches; L, the length of beam between the points of support, in feet; and c, a constant, determined by experiment:

$B=4.5$ $D=4.5$

$L=14.67$, the pontoons being 18′ from axis to axis.

$L=11.33$, the pontoons being 14′ 8″ from axis to axis.

$c=570$,* for American white spruce.

$c=658$,* for American white pine.

Substituting these values, we have for white spruce balks, the pontoons being 18 feet from axis to axis,

$$W=\frac{4.5\times(4.5)^2}{14.67}\times 570=3{,}541 \text{ lbs.};$$

and for white pine balks, with the same pontoon intervals,

$$W=\frac{4.5\times(4.5)^2}{14.67}\times 658=4{,}093 \text{ lbs.};$$

and for white spruce balks, the pontoon being 14′ 8″ from axis to axis,

$$W=\frac{4.5\times(4.5)^2}{11.33}\times 570=4{,}584 \text{ lbs.};$$

and for white pine balks, with the same pontoon intervals,

$$W=\frac{4.5\times(4.5)^2}{11.33}\times 658=5{,}292 \text{ lbs.};$$

Lieut. T. S. Brown, of the U. S. Corps of Engineers, in some experiments made at Fort Adams, Newport Harbor, R. I. (recorded in Silliman's *American Journal of Science and Arts*, p. 228, vol. xix., 1831), found $c=443$, for American white pine (Pinus Strobus); $c=482$, for American spruce (Abies Nigra); and $c=788$, for American southern pine (Pinus Australia). No experiments were made by Lieut. Brown upon American white spruce (Abies Alba).

Strength of Chesses.—The balks being 3′ 0¼″ from axis to axis, the bearing of the chesses, or distance be-

* Tredgold.

tween the points of support, will be 3′ 0¼″−4½″=2′ 7¾″=2.65; applying the same formula, we have for their strength,

$$B=13.5$$
$$D=\ 1.5$$
$$L=\ 2.65$$

$W=\frac{13.5\times(1.5)^2}{2.65}\times 570=6{,}534$ lbs., for white spruce chesses.

$W=\frac{13.5\times(1.5)^2}{2.65}\times 658=7{,}542$ lbs., for white pine chesses.

Strength of Bridge-Flooring.—7,865 lbs. is the maximum weight with which the bridge, with pontoons, 18 feet from axis to axis, can be loaded. In the passage of infantry, cavalry, or artillery, within the capacity of the bridge, the weight would be distributed upon the entire length of at least three balks, strengthened by the stiffness of the chesses. Three balks of white spruce will alone bear 3×3,541 lbs.=10,623 lbs., or of white pine, 3×4,093 lbs.=12,279 lbs., supposing the bearing 14 67′, and the weight applied to the middle; therefore, the strength of the flooring is sufficient for all the purposes of the bridge.

Strength of Pontoons.—Experiment has shown that pontoons, made as described, will safely bear any load sufficient to entirely immerse them in water.

Weight of Bridging.

Weight of Bay of Bridge.—To each bay of 18 feet of bridge, with five balks, the following equipment, exclusive of pontoon, is necessary, weighing—

1 mooring-bar, with becket and part of cable, not immersed	=	14 lbs.
1 pontoon-frame, with lashings, complete	=	98 "
5 balks and lashings	=	428 "
16 chesses	=	832 "
2 side-rails, 6 rack-lashings, and 6 rack-sticks and ties . . .	=	180 "
2 paddles, and 1 boat-hook . .	=	8 "
Weight of 18′ bay, exclusive of pontoon	=	1,560 lbs.

Weight of 1 linear foot of bridge . . . . 87 lbs.

When the balks lap by each other the whole width of the pontoons, the bays will be 14′ 8″, and weigh as above, less the weight of 3′ 8″ of planking of bridge.

Weight of 18′ bay, exclusive of pontoon	=	1,560 lbs.
Weight of 3⅔ running feet of chesses	=	169 "
Weight of bay of 14′ 8″	=	1,391 lbs.
Weight of 1 linear foot of bridge	=	95 lbs.

Flotation of Pontoons.

Flotation of each Pontoon.—Each pontoon consists of three cylinders; each 16 feet long, and 1′ 8″ in diameter, with peaked extremities, each 2 feet long, 1′ 8″ in diameter at the base, and terminating nearly in a point at the end nozzles.

Each cylindrical part	=	35.00 cub. ft.
Two peaked ends	=	5.33 " "
One cylinder, with peaked extremities	=	40.33 " "
Three	=	121.00 " "
Two interspaces, above uniting ligaments	=	9.00 " "
Water, which each pontoon would displace	=	130.00 " "
Weight of displaced water $=130\times 62\frac{1}{2}$ lbs.	=	8,125 lbs.
Weight of pontoon	=	260 "
Flotation of pontoon	=	7,865 "
Weight of displaced water, exclusive of interspaces, $=121\times 62\frac{1}{2}$ lbs.	=	7,562 lbs.
Weight of pontoon	=	260 "
Flotation of pontoon, exclusive of interspaces	=	7,302 lbs.

From the foregoing, we may assume that it would be perfectly safe to load the pontoons with a weight of 7,000 lbs., which would immerse them to within about 3 inches of the pontoon-frames.

Flotation of Middle Air-Chambers of Pontoons.—The ends of the pontoons being much exposed to injury from floating timber and the fire of an enemy, the bridge would sometimes have to be supported by the middle air-chambers alone. These chambers are cylinders 8′ 8″ long, terminated by semi-spheres.

Cubic contents of the three middle air-chambers of each pontoon	=	64.00 cub. ft.
Weight of displaced water $= 64 \times 62\frac{1}{2}$ lbs.	=	4,000 lbs.
Weight of pontoon	=	260 "
Flotation of middle air-chambers	=	3,740 lbs.

Load of Bridge.

Passage of Infantry.—In the passage of floating bridges by infantry, it is indispensable for soldiers to march with the rout step, as the cadenced tread causes oscillations sufficiently violent to endanger the stability of the bridge. An infantry soldier, with arms and baggage, weighs 180 lbs., and occupies in file (including interval), marching with the rout step, 2′ 6″. In retreat, routed, five infantry soldiers will occupy every square yard of the roadway of the bridge. With these data, we find, that each bay of bridge, with pontoons 18 feet from axis to axis, will weigh, loaded with infantry marching in file with the rout step—

$$\text{One abreast,} = \frac{180 \times 18}{2.6} = 1{,}246 \text{ lbs.}$$

$$\text{Weight of bay of bridge} \ . = \underline{1{,}560} \ \text{"}$$

Load of bay, with infantry, one abreast	=	2,806 lbs.
Load of bay, with infantry, two "	=	4,052 "
Load of bay, with infantry, three "	=	5,298 "
Load of bay, with infantry, four "	=	6,544 "
Load of bay, with infantry, five "	=	7,790 "
Load of bay, with infantry, routed	=	23,160 "

From the above, we see that, with pontoons 18′ from axis to axis, a continuous column of infantry can pass the bridge, with perfect safety, four abreast; and, with

extreme care, five abreast; though the latter should not be attempted, except in very urgent cases. When the end-chambers are destroyed, a continuous file of infantry can pass, and by increasing the intervals slightly, a column, two abreast, may cross. For infantry routed, to pass with safety, would require a bridge supported by a continuous line of pontoons, placed side by side, as in the formation of small rafts.

Passage of Cavalry.—In the passage of floating bridges by cavalry, the riders should dismount and lead their horses. The weight of a cavalry soldier and horse, including arms, equipments, and provisions, is about 1,300 lbs. If mounted, the horses, marching by file, will occupy a length of 10 feet, and 12 feet, if led. With these data, we find that each bay of bridge, with pontoons 18 feet from axis to axis, will weigh, loaded with cavalry, marching by file, if mounted—

One abreast $= \frac{1300 \times 18}{10}$ . . . $= 2,340$ lbs.

Weight of bay of bridge . . . $= 1,560$ "

					lbs.
Load of bay, with cavalry (m'nt'd),			one	abreast =	3,900
Do.	do.	do.	two	do. =	6,240
Do.	do.	do.	three	do. =	8,580
Do.	do.	do.	four	do. =	10,920

Cavalry marching by file, the horses being led,

One abreast $= \frac{1300 \times 18}{12}$ . . . $= 1,950$ lbs.

Weight of bay of bridge . . . $= 1,560$ "

					lbs.
Load of bay, with cavalry (hrs. led),			one	abreast =	3,510
Do.	do.	do.	two	do. =	5,460
Do.	do.	do.	three	do. =	7,410
Do.	do.	do.	four	do. =	9,360

From the above, we see that, with the pontoons 18 feet from axis to axis, cavalry (mounted), two abreast, can pass continually with perfect safety, and the horses being led, three abreast, can pass with care; but this latter should not be attempted without urgent necessity. To avoid all risk, it would be better to increase a little the intervals between the horses. The end-chambers being destroyed, a continuous file of cavalry (horses led) can pass with safety.

Passage of Artillery.—The following table shows the respective weights of the various kinds of field and siege artillery carriages, with their loads:

	lbs.
6-pdr. field-gun, carriage, implem'ts, and am'n	=3,049
12 " do. do. do. do.	=4,314
12 " do. howitzer do. do.	=2,978
24 " do. do. do. do.	=3,829
6 " caisson, implements, and ammunition .	=3,454
12 " do. do. do. .	=3,767
12 " howitzer-caisson, implem'ts, and ammu'n	=3,511
24 " do. do. do. do.	=3,824
Battery-wagon for stores, includ'g 250 lbs. forage	=3,710
Do. for harness, do. do.	=3,774
Forge for repairs	=3,023
Forge for shoeing	=3,223
24-pdr. siege-gun and carriage	=9,200
8-inch siege-howitzer do.	=6,250

From the above table it appears, that the 12-pounder field-gun, with its carriage, etc., is the heaviest of the field-artillery train. With six horses, it will occupy 43 running feet of bridge, the weight being, of the

12-pdr. field-gun, etc.	=	4,314 lbs.
6 horses and 3 drivers	=	6,800 "
Load upon 43′ of bridge	=	11,114 lbs.

Load upon each running foot of bridge	=	258 lbs.
Weight of one running foot of bridge	=	87 "
Aggregate, per running foot of bridge	=	345 lbs.

Aggregate of bay, of running feet of bridge = 6,210 lbs.

From the above we see, that, with pontoons 18′ from axis to axis, a continuous train of field-artillery carriages can pass the bridge with safety, supposing the stiffness of the bridge to be sufficient to distribute the load equally over all parts. In practice, it, perhaps, would not be safe so to consider it. Taking, then, the most unfavorable case for the stability of the bridge, which would be when the carriage and pole-horses are upon the same bay of the bridge (barely possible), the four lead-horses of the same carriage on the bay in front, and a pair of the lead-horses of the succeeding carriage on the bay in rear, we should have, to be borne by the two pontoons of the bay supporting the carriage,

Weight of 12-pdr. field-gun, carr'ge, etc.	=	4,314 lbs.
Two pole-horses	=	2,267 "
Half of four lead-horses, and two of succeeding carriage	=	3,400 "
One bay of bridge and two half bays	=	3,120 "
Aggregate to be borne by two pontoons	=	13,101 lbs.

Weight to be borne by each pontoon = 6,550 lbs.

Therefore, a continuous train of field-artillery can pass, with perfect safety, the bridge, with pontoons at 18′ from axis to axis.

A siege 24-pdr. gun-carriage, drawn by eight horses, will occupy 54 running feet of bridge, the weight being, of the

24-pdr. siege-gun, etc. = 9,200 lbs.
8 horses and 4 drivers = 9,000 "
Load upon 54′ of bridge = 18,200 lbs.

Weight on each running foot of bridge = 337 lbs.
Weight of one running foot of bridge = 87 "
Aggregate per running foot of bridge = 424 lbs.
Aggregate per bay of 18 run'g feet of bridge = 7,632 lbs.

From the above, we see, that, with pontoons 18′ feet from axis to axis, a continuous train of siege 24-pdrs. can *possibly* pass, and *without difficulty*, with intervals between the pieces, supposing the load to be equally distributed upon all parts of the bridge. In practice, it would be hardly safe so to consider it; and, therefore, siege-artillery should be passed over streams on rafts, or the bays of the bridge should be lessened.

Placing the pontoons 14′ 8″ from axis to axis, which would allow the balks to lap by each other the whole width of the pontoons, and make the bridge stiff, we should have, as above, the

Weight on each running foot of bridge = 337 lbs.
Weight of one running foot of bridge = 95 "
Aggregate per running foot of bridge = 432 lbs.
Aggregate per bay of $14\frac{2}{3}$ run'g ft. of bridge = 6,336 lbs.

From the above we see, that, with the pontoons 14′ 8″ from axis to axis, a continuous train of 24-pdr. siege-guns can pass the bridge with perfect safety, without

diminishing the number of horses usually required to draw the pieces in campaign.

Passage of Army Trains.—The sapper and miner, the pontoon, the quartermaster's, and the subsistence trains, having no wagons heavier than a 12-pounder field-gun and carriage, can all, of course, be safely passed over the bridge, with pontoons 18′ from axis to axis.

Rotating Pontoons.

An exceedingly simple and apparently meritorious invention was recently brought to the notice of the writer by Hon. P. H. Watson, Assistant Secretary of War. It consisted in constructing wagons, in which the four wheels were replaced by two cylinders, each 6 feet long, and 3½ to 4 feet in diameter. The cylinders were made of wood, put together like staves and strongly hooped. The bed of the wagon formed the floor of the bridge. The wagon carried a movable section, which was to be placed between two consecutive wagons to increase the interval, and also a long light sheet-iron pontoon, which was placed transversely under the movable section and greatly increased the stability.

A single line of these pontoon wagons would make a bridge about 7 feet wide; two lines, one of the ordinary width.

The advantages claimed for this arrangement were greater power of flotation with less weight, and greater facilities of erection and removal than with the ordinary pontoon.

The idea of making the wagon-frame and body form part of the bridge is a good one, and well merits a trial. If the plans of the inventor are not the best possible, experience would soon suggest improvements.

MILITARY BRIDGES IN EUROPE; WITH EXPEDIENTS FOR CROSSING STREAMS, AS EMPLOYED BY THE ENGINEERS OF FRANCE AND ENGLAND.*

Pontoons Used in the British Service.

A PONTOON, of the kind at present in use in the British service, is a hollow, cylindrical vessel of tin, which, being perfectly water-tight, is used for forming bridges for the passage of rivers by armies in the field. Two of these, connected together, with their superstructure and stores, form what is called a *single raft,* on which infantry, cavalry, or light artillery may be conveyed across a river; and two single rafts, connected together, form a *double raft,* on which heavy artillery may be supported.

A pontoon-bridge is formed by the connection of rafts in sufficient number to reach across a river not exceeding 180 yards in breadth, and it is connected with the banks by means of temporary stages or landing-places. Such a bridge is, under some modifications of structure, capable of sustaining troops of all arms, in their passage across a river, as well as of heavy artillery and stores.

The saddle is a frame of fir timber, which is placed centrally over the axis of a pontoon (to which it is secured by lashings), and serves to receive the ends of the balks, which extend from one pontoon to the next.

* From the work of Sir Howard Douglass.

Balks are small beams of fir, resting on the saddles, and secured to them by iron bolts; these form the supports of the flooring of the raft or bridge.

Chesses consist of three fir planks connected together, side by side, by four cleats underneath; and half-chesses are single planks which, in the bridge, lie over the saddles; they are used, in order to afford a ready access to the pins or bolts which pass through the balks.

Each raft, made with two pontoons, consists of two saddles, one on each pontoon; six balks; five whole and two half-chesses; an anchor and cable; six oars for rowing and one for steering; one boat-hook; one buoy-line and one breast-line, with a proportionate number of lashings. Besides these, each raft carries six balks, with five whole and two half-chesses, for the purpose of covering the bay or interval between the raft and that which is next to it in the bridge. The two pontoons, with all the materials here mentioned, are conveyed from place to place on one four-wheeled carriage, which is provided with a perch, and bolsters over the axle-trees.

It would be improper to omit here some notice of a very ingenious nature of pontoon, which was proposed, about 1840, by Sergeant-Major Forbes, of the Royal Sappers and Miners. It is designated an equilateral pontoon; the sides consisting of portions of cylinders supposed to be applied to the three sides of an equilateral triangular prism, each side of the triangle being 2 feet 8 inches long, so that the cylindrical portions meet in three edges parallel to the axis of the pontoon. The sagitta, or versed sine of the curvature, being about one-fifth of the side of the triangle, it follows that each side of the pontoon forms, in a transverse section, an arc of

nearly 90° (87° 12′ 20″). Each end of tne pontoon consists of three curved surfaces, corresponding to the sides of the vessel, and meeting in a point, as if formed on the sides of a triangular pyramid.

The form appears to be well adapted to the purposes of a good pontoon; as, whichever side is uppermost, it presents a boat-like section to the water, and a broad deck for the superstructure. It possesses also the advantage of a horizontal section, gradually enlarging to the highest point of displacement; by which means, stability and steadiness in the water are obtained in a high degree. The area of a transverse section of this pontoon is greater than that of tho present cylindrical pontoon; and the greater capacity produces more than a compensation, in buoyancy, to the small excess of the weight above that of a cylindrical pontoon.

After having been tried two years at Chatham, the equilateral pontoon was given up; some inconvenience in the management of it causing a preference to be given to those of a simple cylindrical form.

A pontoon of the larger kind, at present employed in the British service, consists of a cylinder, 19 feet 6 inches in length and 2 feet 8 inches in diameter, with paraboloidal ends, each 2 feet 6 inches long; the total length of a pontoon is, consequently, 24 feet 6 inches. The pontoons are usually formed of sheet tin, of the quality known in commerce as X X X, framed round a series of light wheels constructed of tin, having hollow tubes of 1 inch diameter for the spokes: the axis is a hollow tin cylinder, 1¾ inches diameter, running through the entire length of the pontoon.

The reason of tin being employed at present as a ma-

terial for pontoons is, that it is much cheaper than copper. On water near the sea, the latter metal is, however, to be preferred, on account of the corrosive action of salt water on tin. It is supposed that copper, tinned, so as readily to take the soldering, would be better than tinned iron; and that tinned iron, galvanized, would be superior to any other metal for pontoons; the iron is first coated with tin, and afterwards with zinc; in which state it is both stronger and lighter than copper; it can be had in sheets, 8 feet long, and of any thickness. This material is largely used for roofing buildings; and, in the colonies, apparently with satisfactory results, for sheathing ships.

The pontoon is internally divided into nine distinct compartments, perfectly water-tight, and independent of each other. It is provided with four rows of sunken handles, placed at intervals of 2 feet, 1 inch round the circumference, for the purpose of lashing to it the saddles, which are placed on it, to form the bearings of the balks which support the superstructure of the bridge; each end has a stout iron ring securely attached to it.

Russian Pontoons.

The Russians use bateaux, or flat-bottomed pontoons, made of sail-cloth or canvas, stretched over a framework of wood; this is so constructed, that the centre-pieces, or thwarts, may be unshipped: the side-frames are then taken off, and the whole packed in small space on a wagon. The canvas is well tarred, or covered with a strong varnish, being a solution of gum elastic (india-rubber). This varnish is composed of hemp-seed oil, strong loam, gum elastic, soap, wax, and soot. The

india-rubber is first put into boiling water to soften; it is then cut into small pieces, and kept for about twenty-four hours in a covered vessel in hot water. It is then heated, by portions, in an iron pot with oil of hemp-seed, till dissolved. The whole is then put into one vessel; soap and beeswax are then added, and the compound heated and stirred till the mixture is complete. It is then suffered to cool. A compound of flour and soot, pounded together, and mixed up with hot oil, having been prepared, is added to the solution of the gum elastic, when that mixture is sufficiently cool to admit the hand. The paste being rubbed down, reduced, and the mixture well stirred together, the whole is again boiled for a quarter of an hour, and applied when hot, but not boiling, on both sides of the canvas, with brushes, and well rubbed into the pores and seams of the cover, previously made up, of the pontoon.

Pontoons of Planks and Logs.

In countries where timber is plenty, a pontoon or ferry-boat may quickly be made thus: Fell seven trees, of about 16 inches diameter, and cut off 18 feet length from each. Lay five of these on any level spot, parallel to each other, at 3 feet asunder, and reduce their upper surfaces to a level. Plank them throughout. If nails are not at hand, treenails (wooden pins) will answer. If planks cannot be had ready made, set sawyers to cut up the first trees that can be felled. If tow or oakum is not to be found, rushes, or even moss, with tallow and beeswax, will answer for immediate use. As soon as the platform is calked, turn it over, and bolt down the two remaining trees over the ends of those forming the plat-

form. Plank the sides and ends of the vessel, taking care that the bottom planks overlay the sides; otherwise the nails would be driven into the ends of the planks forming the bottom, on two sides of the vessel, and would not hold. The flat thus formed would be about 18 feet square, and about 34 inches deep.

Provision for the passage of rivers, in the earlier operations of ordinary marches, may be made without much difficulty, for they are nearer to resources that may be made available. But when, after having crossed many rivers which may have become fordable, the passage of others which are unfordable is to be undertaken near to, or in presence of, an enemy, the operation will entirely depend upon the state of the bridge equipment which the army may have brought with it, or upon the means which may be found on the rivers in the seat of the operation. Upon the latter it is never prudent to depend. An army relying altogether upon these is never safe, and ought not to be successful. Whatever be its qualities and its force, the operation in which it is engaged will depend mainly upon material means; and there can be no more discreditable cause of failure on the one hand, and no more obvious means of producing it on the other, than for an army to trust to such contingencies. Such a deficiency, if properly taken advantage of, might, more than any other circumstances, compromise the safety of corps, arrest their progress, and lead to the most serious results. It does not require great research to discover how much truth there is in this observation.

The progress of corps, unprovided with the means of constructing regular bridges, from bank to bank, must depend on the intelligence, resources, and experience of

the officers, in availing themselves of whatever materials may offer, or can be procured on the spot, and on the ability and promptitude with which these irregular means may be thrown together. To enable officers to effect this, the marching corps should always be accompanied by a body of men well versed in such expedients, and provided with a supply of cables, ropes, light anchors, blocks, nails, and such other materials as are portable and requisite for making the most of the limited resources which are to be found on rivers of no established navigation, and upon which what little there is may be easily destroyed, and where timber can only be had by the deplorable expedient of unroofing houses.

A simple raft, consisting of two iron cylinders, each 40 feet long and 30 inches in diameter, placed 4½ feet asunder, between their axes, has also been recently invented by Mr. Richardson. It was easily rowed by six men; and eighty men, standing on one side, failed to overset it. This is proposed as a life-raft; but it may also be employed for the formation of military bridges.

Bridges by Conversion.

Bridges are sometimes constructed in creeks, or behind islands, where the operations are concealed from the enemy; and, when used, floated entire, or in large sections, and thrown suddenly across, by a manœuvre of conversion. The following account of the construction of a bridge across the Danube, by Napoleon, at the island of Lobau, will afford an illustration:

The bridge near the island of Lobau was composed of fourteen Austrian bateaux. It was formed of four

pieces, or rafts; two of the rafts were of four bateaux, and the two others of three bateaux each. There were but three balks to each bay, as the bridge was only for the passage of infantry. The boats were placed about 34 feet distant, from centre to centre; the bays were, consequently, about 28 feet wide each.

The balks overlapped each other, and rested on both gunwales of the boats, projecting about a foot on each side; each pair of balks was bolted together in the middle of the boat, and kept at equal distances from each other by small blocks of wood, placed between them on the gunwales, and held together by cleats butting against the exterior balks, and pinned to the gunwales. The balks were about 42 feet long, and 8 inches square, and were all clamped to the sides of the boats by iron clamps.

The following is a list of the materials used in the construction, viz.:

Forty-five balks, of which thirty-nine were for connecting the boats with each other, and six for the ramps, or for connecting the end boats with the banks. Thirty pieces of scantling, or balks, each 35 feet long and 6 inches square, for racking down the planks or flooring of the bridge at the sides; their ends, cut so as to overlap each other, were bolted together—the bolt passing through the flooring and the balk below. Fifteen traverses, or cross-pieces of wood, mortised to receive the balks, into which they were also let, so that, when properly fixed, their upper surfaces were flush with the upper surfaces of the balks. They were placed in the middle, between every two boats, to bind the balks together, and also to keep them at the proper distances from each other.

Fifty-six small blocks of wood, placed on the gunwales

of the boats, four to each boat, between the balks, to keep them at equal distances from each other.

Fifty-six cleats, four to each boat, nailed to the gunwales of the boats, butting against the exterior balks, and thus binding the whole together.

Fifty-six braces, four to each boat, 9 feet long, and about 4 inches square, one end bolted to the gunwales, the other end bearing against, and bolted to the exterior balks, by which they were kept in the proper position.

Five hundred and ten planks, 7 feet long, 1 foot broad, and 1½ inch or 2 inches thick, for flooring.

Eighty-four clamps, six to each boat, for securing together each pair of balks, and for fastening them to the exterior sides of the boats.

Forty-two bolts, with nuts, passing through each pair of balks, fore and aft, in the middle of each boat.

Two sheer-lines, or ropes, extending from one bank to the other, passing through the rings in the heads and sterns of the boats.

The rafts had separate sheer-lines, distinct from each other, but so arranged that they might be readily joined together, or cast loose. This was accomplished by having an eye-splice at one end, through which the plain end of the other line was passed, and made fast.

The spring-lines were arranged in a similar manner, and passed through holes in the sides of the boats, under the gunwales.

Two long guy-ropes, of 100 fathoms each, for swinging the bridge, were fixed to the farther end, and eased off when the bridge was swinging, so that its motion should be moderate and uniform.

Ten anchors, of which seven were stream anchors, being one anchor to every two boats.

Ten cables and buoys.

Two crab capstans, for hauling tight the hawsers at the heads and sterns of the boats.

Ten large pickets, shod with iron.

Twenty-eight oars.

Fourteen boat-hooks.

Scoops for bailing; hand-pumps; besides spare rope, straps, lashings, etc., etc.

In taking the bridge down the narrow channel where it was constructed, in order to shorten it as much as possible, and to enable it to follow the bend of the stream, the rafts were attached to each other by ropes, and the fixed balks of the exterior boat of each raft placed on a roller, laid on the flooring or balks of the end boat of the adjoining raft, so that, in turning or winding, the balks might move from side to side on the roller, attention being paid not to let them get off it.

When the direction of the narrow channel became straight, and led directly into the main branch of the river, the different parts, or rafts, were put together. One squad of pontoniers arranged and set the balks in their places, and secured them to each other; another squad fixed the clamps which fastened the balks to the gunwales, and arranged and fixed the blocks of wood and the cleats; while a third squad arranged the braces or oblique shores, laid the flooring, and then bolted the racking balks. Whilst this was doing, the bridge was allowed to descend, attended by other pontoniers, divided into six squads. The first squad carried the ends of the sheer-lines, ready to fix them on the right or

occupied bank of the river. The second squad carried the guy-ropes, of 100 toises each, one end of which was fixed to the end of the bridge which was to reach the opposite bank: when the bridge was to be swung across, the rope was passed round a tree, and the men of the squad, holding on the other part of the rope, eased it off as the bridge was swinging, and thus kept it straight, and made its motion uniform. The third squad had charge of the anchors, to cast them at the proper times. The fourth squad, provided with long boat-hooks, modified and regulated the movement of the bridge while it was swinging. The fifth squad, in a boat, attended the bridge as a reserve, to assist or strengthen any other squad. The sixth squad attended in small boats, with anchors ready to be applied at any points where the bridge, in swinging, might seem likely to bend.

When the bridge arrived in the main branch of the river, it was allowed to descend for about 250 yards along the right or near bank, after which it was swung across in the following manner:

The first squad fixed their sheer-lines to two trees.

The second squad, having passed their guy round a tree, pushed off the end of the bridge which was to reach the opposite bank, being assisted in the operation by the fourth squad, with their boat-hooks.

The second squad then eased off the guy-rope, in proportion as the bridge swung with the current.

The third squad cast the anchors in succession, and brought the cables to the boat opposite to the anchor, where they veered away cable, or held on, as circumstances required.

The operation of swinging the bridge was performed

in four or five minutes; and, at about 11 o'clock at night, a division of infantry passed.

Pickets were driven for the sheer and spring lines, and capstans fixed on the enemy's side, or left bank of the river, whilst the troops were filing across.

Flying Bridges.

A flying bridge is formed by anchoring a floating body in a river, so as to receive the action of the stream obliquely, by which a force is derived from the current to move the vessel across the river.

The force which urges a vessel, G F (Fig. 1, Pl. LVI.) perpendicularly to the current, depends upon the obliquity of the vessel; and is a maximum when the side G E makes, with a line parallel to the direction of the current, an angle of 54° 44′.

But this value is correct only on the supposition that the keel of the vessel is moved, parallel to itself, on a line perpendicular to the direction of the current. If, as is usual, the vessel be made to describe a circular arc across the river; if, for example, a cable affixed at one end to its mast were attached, at the other end, to a buoy moored as at B (Fig. 2), in the middle of the stream, the force by which the vessel is impelled across the river being then estimated in a direction perpendicular to that of the cable, the angle which the side or keel of the vessel should make with the direction of the current, when the force is a maximum, varies continually.

The force of the current upon E F, the end of the boat, acts in part against the force L C, and therefore vessels for flying bridges should be long and narrow; and flat-headed boats should not be used unless their breadth is very small.

The boat A (Fig. 2, Pl. LVI.), fastened by a cable to a buoy, B, securely anchored, will, in crossing from C, soon come into the line of direction of the current B D; and if she be steered in a proper degree of obliquity, she will pass through the ascending part of the arc to the bank E, whence she may be made to recross to C in the same manner.

The manœuvre will be more easily executed with a long than with a short cable, for it will be in the arc of a large circle. If a short cable, B C, were used, the boat would have to ascend from G through a space equal to G H, to arrive at S, and consequently suffer great resistance from the action of the current. Also, resolving B S into B H, H S, we see that the force B H supports the boat against the stream, whilst it is held to the centre, B, by the greater force, H S. The movement, therefore, should not be made in a longer arc than 90°; and when this rule is observed, the angle A B E never being above 45°, the force E O will never be greater than O B. Whenever a long service of cable is used, it should be floated by intermediate buoys (1, 2, 3, Fig. 3, Pl. LVI.).

When a river is too wide for a simple flying bridge on this scale, the boats may be sheered (to sheer is a sea-term for causing a vessel to move athwart a current, by receiving its action obliquely) across the current by warps to two or more buoys; or two boats may be used, one moving in the arc C D (Fig. 1, Pl. LV.) upon the centre, A, the other describing E F, upon B; a boat, or raft, being moored in the middle of the river, for the convenience of shifting troops from one to the other. Or, which is much better, the cables may be exchanged

when the boats come close to each other: thus the boat D, falling into the arc E F, resigns its arc, or path, to the boat E. Or the boat A (Fig. 3, Pl. LV.), attached to a block running on a cable, B C, stretched across the river, and kept in an oblique position, will move across the river on the cable. In this manner a communication was established across the Thames, at Gravesend, during the threat of invasion, when it was of great importance to have a well-established military communication between that place and Tilbury Fort, without interrupting the navigation of the river.

A species of flying bridge, on this principle, which has been used with advantage on the rivers of India, consists of a single boat, or a raft formed with two boats, and capable of carrying 100 men. A hempen cable, exceeding in length the breadth of the river, is attached at the extremities to two wooden standards, planted in beds of masonry on the opposite bank: on this cable run two traversing blocks with their tackles, the latter being made fast to one side of the boat or raft, near the head and stern. The height of the standards is great enough to keep the cable above the highest flood-line, and, by hauling on, or letting out the *after* tackle, the boat is kept in a position oblique to the current, which thus impels the vessel across, in a direction parallel to the cable. No rudder is necessary.

In a rapid current, the resistance against a flying bridge, in the ascending part of the arc, may sometimes be too great to be encountered with safety; to avoid this, two ropes may be used, and the passage made in a descending arc. Thus, the boat A (Fig. 2, Pl. LV.) crosses to the bank E through a descending arc, D E, taking with

her the rope A C, by which she recrosses from the point F, to which she must be hauled up, from E, when close to the shore.

Partial applications of the flying bridge may thus be of great service in enterprises of a bold, desultory character, when anchors cannot be laid, or there might be danger in attempting to use them. Let the boat be sheered off from the bank D (Fig. 4, Pl. LVI.), by a cable fastened to B, until, from the impetuosity of the current, it becomes necessary to let go; if the boat be kept in the proper degree of obliquity by oars, the current will set her to the other side as she descends, and she will reach the bank, as at G.

Whenever a current is so strong as to render it difficult or unsafe to sheer a boat across with cables, it will be absolutely necessary to steer it with a long oar, because a rudder cannot control the sudden impulses of a powerful eddy, or an irregular current.

In this case it will be better to attempt the passage of a river at a curved part, because the rapidity of the stream on the concave bank occasions an eddy upwards towards the point E (Fig. 4, Pl. LVI.), which will carry the boat to F, where, assisted by a rope, she may again take the stream obliquely, and easily reach the other side, as at K. To return, the rope A C (Fig. 4), should be used to sheer her to A, whence, if a proper obliquity be maintained, she will fall into the eddy, and easily regain the point H.

To construct a flying bridge on rivers of considerable magnitude, such as the Rhine and the Danube, two large boats or vessels (Fig. 2, Pl. LIV.) are commonly used.

The vessels constructed or fitted for this purpose

should be long, narrow, and deep; and their sides vertical. They are placed parallel to each other; the distance asunder being, to a certain extent, regulated by their length. In order to derive as much force as possible from the current, to act upon and cause the bridge to cross the stream, the boats should be so far apart as to allow it to act upon the whole length of the plane side of the lower boat. Thus the angle A C E (Fig. 1, Pl. LVI.), being 54° 44′, the distance of a boat so placed with respect to the boat G F, should be equal to the tangent of the angle A C E; G E, the length of the boat, being considered as the radius of the circle; but such an interval might be inconvenient or impracticable. The distance should therefore be regulated so that, whilst this object is kept in view, the platform and connection of the boats should have the necessary degree of strength and resistance for the weights to be transported, and the strains to which this nature of bridge is commonly, and sometimes greatly, exposed.

If the current be rapid, and the strongest part nearer to one side than to the other, the anchor should not be placed in the strongest part of the current, but near or on that edge of it which is not on the side to which it is tending; for if the anchor be placed in the strength of the current, it will be less likely to find good holding ground there than in parts where the current acts with less force on the soil at the bottom of the river, on the tenacity and depth of which *good anchorage* depends. If, moreover, the bridge moves upon an anchor laid in the strength of the current, instead of being placed in the middle of the river, the motion of the bridge will not be equable; it will pass too easily, or forci-

bly, in one direction, and with more difficulty in the other.

The "*Handbuch der Pontonnier Wissenschaften*," states that, in rivers which do not exceed 150 feet in width, one anchor of about 300 or 350 lbs. weight will be sufficient; but for such cases as we are now considering, three anchors should be used; one of about 500 lbs., laid in the centre, and one of 300 lbs. on either side; the three cables being united near the first boat, at lengths to suit the several strains. The shank of the main anchor is laid in the direction of the current; the shanks of the other two should be placed in directions to correspond with those which the cable takes in the extreme position of the vessel on each side. With one anchor only, it is clear that at every trip it would be moved in the ground, to follow the direction of the strain upon its cable; and, unless the soil be of great tenacity, this must, by degrees, cause the anchor to shift its place downwards.

The length of the cable, or chain, should be at least 1½ times the chord of the arc which the bridge describes.

With small bridges (Fig. 3, Pl. LVI, and Fig. 1, Pl. LV.), it will only be necessary to float the cable by means of buoys; but for a flying bridge on a large scale (as shown in Fig. 2, Pl. LIV.), boats (as 1, 2, 3, 4, Fig. 6) should be substituted for buoys, as for the body of the bridge, so these boats (excepting that nearest the anchors) should be long, deep, narrow, and with vertical sides. The first boat (1, Fig. 6, Pl. LIV.) should be the largest, widest, and most powerful; for in it, placed longitudinally from head to stern, the cable or chain is laid; and, not being in a direct vertical plane between

the mast-heads of the vessels and the anchors (Fig. 6), this boat has to bear a considerable portion of the weight of the cable, as well as to resist a great strain, whilst the bridge is in the stream and working most upon the cable. The other boats (2, 3, 4,) are smaller, in proportion to their distance from the centre of motion; and are provided with masts, having forked heads, by which to support the cable or chain, at altitudes which increase in proportion as they are nearer to the vessel. The masts are placed near the heads of the boats, and their sterns are attached to the cable or chain by spring-lines of proper length to limit, in a suitable degree, the obliquity which they naturally assume in following the movement of the bridge. These boats should be decked, to save the trouble and expense of watching and attending them, in order to bail or pump out rain-water, or that which, if not decked, might be thrown in by heavy swell.

A flying bridge may also be made of one vessel. When the current is rapid from bank to bank, and the vessel large, it should be fitted with a strong mast, placed, as in the preceding case, at about one-third of the vessel's length from the head; a lifting bridge is constructed on each side; a windlass placed at the stern; and the whole is managed in every respect as directed in the foregoing description.

For a flying bridge on a small scale, on rivers of moderate rapidity, the vessel (Figs. 7, 8, Pl. LIV.) may be fitted so as to expose but one of its sides to the action of the current in passing and repassing the river; this may be easily accomplished if the communication can be established at any part of the river where the current is

swerving from one bank towards the other, and, consequently, not setting in strength close to either side (and it should be observed that this is always the case between two sinuosities, Fig. 2, Pl. LVII., a little below the part marked by the line of asterisks, that is, nearer to the point R than to the point M); thus leaving the right bank *above* the part to which the current is setting, and arriving at the other bank *below* the point from which the current has swerved. There are several advantages and facilities in such an arrangement. The mast not being in the centre of the body of the vessel, but placed in the middle of one of its sides (Fig. 8, Pl. LIV.), the whole interior space is left clear; the boat is brought endways to the shore, being of an easy draught of water at the ends; and these being made to project (or rake) considerably, the communication with the shore on each side is easily effected, without the necessity of constructing lifting bridges, or providing wharves. The mast, fixed in the centre of the side (Fig. 8), is well secured by stays to the other side of the vessel. The cable or chain passes through a block at the mast-head, and from thence to the opposite side, where there are two pins and tackles for regulating its length, and for fixing it at parts which correspond in direction with the two strains in the two paths of the vessel. The tackles are fixed to the cable or chain at E (Fig. 7), one leading to F and the other to G. The former being tightened sufficiently, and the other, G, let go, the boat is caused to take a degree of obliquity in the current, which may be properly regulated by a powerful steering oar, and further assisted by the current-board H; this last being lowered, for the purpose of presenting a vertical surface

for the stream to act upon, in order to make up for the deficiency in this respect which the shallowness of the vessel towards the ends (that she may approach close to the bank) necessarily occasions. To return from tho side to which the vessel (Fig. 7) is represented as approaching, the current-board H is raised by a tackle to G, the tackle E F let go, and E G hauled upon; the current-board I is then lowered, when all the forces which caused the boat to pass will be reversed, and bring her back to the previous point of departure.

This and the preceding details of the large flying bridge (Figs. 2, 3, 4, 5, and 6) are taken from actual constructions and practice which the author witnessed in a late military tour.

A flying bridge, or rather a ferry bridge, was established on the Tagus, at Villa Velha, by stretching a hawser across the river, and attaching to it, by a ring or "traveller," a raft, formed of a platform, laid upon two boats. This double vessel or raft was worked backwards and forwards, by detachments of twelve seamen, relieving each other at regular intervals, from a party stationed there for the purpose. This principle of warping across is very commonly used for ferries, and is worked by two or three men with button nippers attached to man harness, and this expedient may be adopted with convenience and advantage in small rivers, whose current does not exceed two miles an hour; but, beyond this, the flying bridge principle should be either fully or partially followed, according to circumstances, as represented in the foregoing plates and descriptions.

When it is intended to force the passage of a river by a flying bridge, the great aim must be to conceal the

point of debarkation. It will not, therefore, be possible to sink an anchor or anchors beforehand. If this cannot be effected at the moment of undertaking the operation, a considerable number of oars may be used to row the machine aslant the current as she descends.

Parapets of timber, wool, or sand-bags may be constructed on the most exposed sides, to protect the troops from musketry or grape-shot, and pumps should be ready, in case of being struck by large shot under the water-line.

This kind of desultory enterprise admits of some deviation from the practice that should be observed in the passage of rivers by more regular means. Success will be promoted by carefully concealing the points of embarkation; and, in this view, there is reason to prefer making it at salients, rather than at re-entering parts. Lest it be said, that the principle from which this rule deviates admits of no exception, the author repeats, that re-entering sinuosities are chosen as the best situations for continuous bridges, on account of the protection which the bend affords to the bridge, and the *appui* it gives to the formation of troops, and to the *tête-du-pont;* but this is not essential in operations of irregular character, favored by stratagem, which suppose the force of the enemy not to be so great as to require much circumspection: Debarkations made at P or D (Fig. 1, Pl. LVII.) will be less likely to be disputed than at C, where they are generally expected; besides which, there are reasons, arising from local circumstances, which deserve notice. The chief difficulties to which an enterprise of this nature is exposed, are those of the rafts getting aground, or being baffled by eddies. To both of

these the operation would be more exposed in an attempt to land at C than at D. For we have seen that in a bend corresponding to E C G, there will be an eddy and little depth, and that the bank and bottom will, in general, be soft. If this be not so in any considerable degree, yet, as the bank there is always shelving (D B, Fig. 3, Pl. LVII.), the float (which will draw, at least, four feet of water) will take the ground at a distance from the shore. But let the float be directed in the line H I (Fig. 1, Pl. LVII.), to land it at D; the current, setting into the bend, will carry it towards its destined point; and, as we have seen that the water deepens towards that side (Fig. 3, Pl. LVII.), and forms a bold or steep bank there, the two great causes of failure, incidental to the other, will not operate in this.

The principle of the flying bridge should be well understood by all classes of officers, particularly the staff; as it may be applied, either wholly or partially, to boats or rafts of any kind, and on every scale, for passing small, as well as large rivers.

These are particularly useful in all enterprises of a bold, desultory character; and are essential in attempting to pass a river in face of an enemy, either by stratagem, or by a combination of force with it.

Attempts to pass rivers by pure, open force, in face of an enemy, aware of the intention, have occasionally succeeded in an astonishing degree, considering the disadvantage under which the assailants act, if they do not resort to stratagem, by which to effect a surprise; but such attempts have frequently failed, and the instances of success stand recorded in professional history as enterprises of rash bravery, which ought not to have suc-

ceeded; and which, in general, have done so either on account of their unexpected audacity, or from being carelessly watched and feebly opposed, and are not cited as models to be followed. The great King of Prussia, in his instructions to his general officers, condemns all attempts to force the passage of a river without having recourse to stratagem.

From all the brilliant instances of success which history affords, where stratagem has been properly combined with force, and from the doubtful issue and frequent failure of those of open force alone, it appears that, in attempting the passage of a river, the first operations should always be undertaken with detached means, such as row-boats, rafts, flying bridges, prepared behind islands, or in streams which adjoin to the river which it is intended to pass, but kept concealed until the passage is to be attempted; that every practicable *ruse* be devised, to keep the enemy in doubt as to the point upon which the landing is to be made; and that means for constructing regular bridges should be held in perfect readiness, to support the troops by which the first lodgements are effected, by establishing, as quickly as possible, continuous communication with them. A lodgement made on a river bank, like that established on the ramparts of an assaulted fortress, will seldom fail in leading to its capture, if that lodgement be properly made, promptly supported, and discreetly managed. It is generally from too much being attempted, in the preliminary stages of attacks, by troops hurried forward by impatient ardor, that reverses occur. A footing once gained, is a fulcrum which should never be lost, and never is it so but by misconduct.

Bridges on Rafts of Timber, Casks, Air-tight Cases, and Inflated Skins.

In mountainous countries the difficulty of transporting pontoons, or other means, for constructing bridges, frequently reduces armies to the necessity of employing, for that purpose, such materials as are found in the vicinity of the rivers.

When timber, proper for rafts, is abundant near the banks of a river, this is one of the most useful expedients that can be employed.

Raft-bridges of timber may be used on almost any river, provided the velocity of the current does not exceed six feet per second; with a greater velocity it would be scarcely possible to fix the rafts, and the shocks which the bridge would experience from bodies floating down the stream, would soon cause its destruction.

Rafts are prepared with little difficulty beyond that of cutting and collecting timber; they may be formed of a size capable of transporting a considerable number of troops at once, upon the principle of a flying bridge, or may be used as floats, upon which to form a connected bridge.

The buoyancy of rafts, consisting of trunks of trees or logs of squared timber, depends on the hydrostatical fact, that a body floating in water displaces a quantity of fluid, whose weight is equal to that of the floating body; and it follows that the specific gravity of the timber employed in the formation of the raft, must be less than that of the water in which the raft is to float. It is evident that timber of the least possible specific gravity that can be procured, should be used in preference to any other.

The following table of the specific gravities of wood, will serve to show the kinds of timber which may be employed in the formation of rafts, and will afford the means of computing their buoyancy, or the weight which they will support when in water. The numbers express the weight of a cubic foot of the material, supposed to be dry, in avoirdupois ounces; and they may be used for timber which is cut down in autumn or winter; but in spring or summer, when the trees are full of sap, the numbers should be something higher.

The specific gravity, or the weight of a cubic foot of fresh water, is 1,000 ounces, or 62½ lbs.

Table of the specific gravities of woods, compiled from the experiments of M. Muschenbroek, and those of Mr. Couch, of Plymouth, as quoted by Mr. P. Barlow. The materials which are marked with an asterisk, will not float in water:

Alder	800	Filbert-tree	600
Apple-tree	793	Fir, Riga (inferior, or female, kind)	479
Ash (the trunk)	845	" " (superior, or male, kind)	598
Bay-tree	822	" (Scotch)	696
Beech	852	" Spruce (Canadian)	518
Box (French)	912	" " (from Halifax)	567
" (Brazilian red)*	1,031	Hazel	600
" (Dutch)*	1,328	Jasmine (Spanish)	770
Campeachy-wood	913	Juniper-tree	556
Cedar (Spanish American)	561	Larch (Scotch)	530
" (Wild)	596	Lemon-tree	703
" (from Palestine)	613	Lignum vitæ*	1,333
" (Canadian)	753	Lime, or Linden-tree	604
" (Indian)*	1,315	Logwood	931
Cherry-tree	715	Mahogany	637 to 1,063
Citron	726	Maple	750
Cocoa-wood*	1,040	Mastic-tree	849
Cork	240	Medlar	944
Cypress (Spanish)	644	Mulberry-tree (Spanish)	897
Ebony (Indian)*	1,209	Orange-tree	705
" (American)*	1,331	Olive-tree	927
Elder-tree	695		
Elm (English)	588 to 800		

Oak (English)	750	Poplar (English) . . .	383
" heart of*	1,170	" white (Spanish) .	529
" bog (from Ireland)* .	1,046	Poon-tree (East Indies) .	635
Pear-tree	646 to 661	Quince-tree	705
Pine, white (from New Brunswick)	492	Sassafras	482
" " (United States)	426	Teak	666
" yellow (Canadian) .	440	Vine*	1,327
" northern (New York	482	Walnut-tree	671
" red (ditto)	536	Willow	585
" pitch (Virginia) . .	563	Yellow-wood (Cape of Good Hope)	643
" ditto (Baltimore) . .	632	Yew (Dutch)	788
Plum-tree	785	" (Spanish)	807
Pomegranate-tree* . . .	1,354		

In order to find the buoyancy of a timber raft, it is necessary, first, to compute the volume of each trunk of tree composing it—to add all the volumes together, and then to multiply the sum by the tabular number, expressing the specific gravity of the kind of wood; the product will denote, in ounces, the weight of the raft. The same sum, being multiplied by 1,000, gives, in ounces, the weight of an equal volume of fresh water; and the difference between the products will express the buoyancy of the raft, or the burden which it will support when sunk, till its upper surface coincides with the surface of the water.

The trunk, or log of timber, being considered as the frustum of a pyramid or cone, its volume will be correctly found by the following rule: *Add together the areas of the two ends and their mean proportional, and multiply the sum by one-third of the length.*

But either of the two following rules, which, in practice, are sufficiently near the truth, for trunks of trees, may be used: 1. *Take a mean of the girths (or circumference) at the ends, in feet and decimals; multiply its square by the decimal* .07956 (*the area of a circle whose*

circumference is 1), *and multiply the product by the length of the trunk.* 2. *Multiply the square of one-fifth of the mean girth by twice the length of the trunk.*

Squared timber may often be procured from timber-yards, or from the ruins of houses, barns, and the like; and if a piece have the form of a parallelopiped, its volume will be obtained correctly, by multiplying together its length, breadth, and thickness. Should the piece have the form of a frustum of a pyramid, the volume may be obtained, approximatively, on multiplying together the length, the mean breadth, and the mean thickness.

The following table contains the solid contents, or volume, of round timber, of such dimensions as are most likely to be applied in the formation of rafts. From it, the number of pieces necessary to float a given burden may easily be determined, by means of the table of specific gravities.

Length. Feet.	Mean Girth. Inches.	Contents. Feet.	Length. Feet.	Mean Girth. Inches.	Contents. Feet.
25		12.5	25		43.54
30	30	15.	30	56	52.25
35		17.5	35		60.96
25		14.21	25		46.72
30	32	17.06	30	58	56.06
35		19.9	35		65.4
25		16.05	25		50.
30	34	19.26	30	60	60.
35		22.47	35		70.
25		18.	25		53.37
30	36	21.6	30	62	64.05
35		25.2	35		74.72
25		20.05	25		56.88
30	38	24.06	30	64	68.26
35		28.07	35		79.64
25		22.22	25		60.5
30	40	26.66	30	66	72.6
35		31.11	35		84.7
25		24.5	25		64.21
30	42	29.4	30	68	77.05
35		34.3	35		89.89
25		26.88	25		68.05
30	44	32.25	30	70	81.66
35		37.63	35		95.27
25		32.	25		72.
30	48	38.4	30	72	86.4
35		44.8	35		100.8
25		34.71	25		76.4
30	50	41.65	30	74	91 25
35		48.6	35		106.5
25		37.55	25		80.21
30	52	45.06	30	76	96.26
35		52.57	35		112.3
25		40.5	25		84.5
30	54	48.6	30	78	101.4
35		56.7	35		118.3

Three lengths are given in the above table for each mean girth, from 2 feet 6 inches to 6 feet 6 inches; be-

yond which magnitudes, timber is either too small to be of use, without connecting a vast number of pieces, or too large to be readily removed from the place where it is felled.

If a bridge or raft is to remain long in the water, the ends of the trees should be tarred; notwithstanding this precaution, however, water will be imbibed by the wood, and therefore some allowance should be made for the loss of buoyancy arising from this circumstance, in calculating the quantity of timber to be put into a raft.

In colonial service, timber of unknown specific gravity may be more abundant than any mentioned in the table; it is therefore necessary to know how to ascertain the specific gravity of timber, in order to select that which is most proper. Weigh any sound part in and out of water; and the difference will be the weight lost in water. Then, as the weight lost is to the whole weight, so is the specific gravity of water to that of the wood. Thus, the weight of a cubic foot of fresh water is 1,000 ozs., and that of sea water is 1,026 ozs. Now the weight of a cubic foot of the best Riga fir is 598 ozs.; therefore, a cubic foot of this wood will support 402 ozs. in fresh, and 428 ozs. in sea water. Hence, if the contents of a tree, in feet, be multiplied by the difference between its specific gravity and that of the fluid, the product will be the weight, in ounces, which the tree will float.

If timber cannot be floated to the place where it is to be formed into rafts, every exertion should be made to collect carriages in the country; but, if such cannot be found, the carriage part of an ammunition wagon may be used as a timber-tug, by removing the boxes, and

fastening a block of wood over the axle-tree. The trail or perch will serve as a lever to raise the timber, in the same manner as a wood sling-cart is used; but, as the projection of the back part of the carriage will prevent its being put sufficiently erect to sling the load at one operation, it must be repeated by blocking up the timber, and taking a fresh purchase.

The wheels being 5 ft. in diameter, a tree of 1 ft. 9 in. diameter may be slung in this way, leaving a considerable space between the under part of the tree and the bearing part of the wheels, to allow for penetration in soft ground.

The girth of this diameter (1·75 feet) is 5·5; and, if the length of the tree be 25 feet, its cubic contents will be 60·5. If fir, the weight will be about 2,079 lbs., or 19 cwt. nearly, which the four horses of the wagon will be able to draw in almost any road.

But in deep ruts, or soft ground, timber of any considerable size cannot be conveyed in this manner; in this case a wood carriage may be made of an ammunition wagon and its limber, by removing the limber-boxes, and fastening a block of wood over the axle-tree, as in the former case with the wagon. The small end of the tree is first raised by a gin, and the limber backed under it; the large end is then raised in the same manner, and placed upon the body of the wagon, the trail of which is lashed to the tree, and to the limber-hook. The small end of the tree is placed upon the limber, that the tree may move easily upon the block when the carriage turns out of the straight direction; which it will do the better from the weight and contact being less, than if the large end were put upon the limber.

Bridges of rafts being, in general, only temporary expedients resorted to upon sudden emergencies, the construction should be such as to effect the purpose with the least means consistent with safety; and this we are now to consider.

A fir-tree of 4·33 feet mean girth, and 30 in length, contains 44·9 cubic feet, and will float 1,128 lbs.; six of these (Fig. 1, Pl. LVIII.) will float 6,768 lbs. Deduct the weight of five balks of oak, 4 inches wide, 6 inches deep, and 26 feet long; also the weight of 2-inch planks, sufficient for a floor 10 feet wide and 12 long; in all, about 1,981 lbs.; and there will remain 4,787 lbs. for the weight which each raft is capable of bearing. If the rafts are 12 feet distant from centre to centre, and the whole bridge covered with infantry filing across, each will have to sustain twelve men nearly; which, taken at 180 lbs. per man, is 2,160 lbs.; leaving 2,627 lbs. for the remaining buoyancy of each raft.

If the timber be well seasoned, and has not been long in the water, infantry may pass under a front of four men, ranks 30 inches from each other, by which each raft will have to bear sixteen men (2,880 lbs.); retaining a buoyancy, by calculation, of 1,907 lbs. But, in general, the excess by calculation should be greater than this, to allow for loss* and deficiency† of buoyancy.

The mean diameter of a tree whose mean girth is 4·33 feet, is 1·38 feet. A raft of six trees of this size will be 8·28 feet wide; and the interval between two rafts, placed 12 feet between centres, will be 3·72 feet; a

* By imbibing water. If the ends are not tarred, dry timber will increase its weight one-sixth by two or three days immersion.

† By being full of sap when cut.

space sufficient to allow a great part of the superficial current to pass.

Cavalry may pass by twos; but intervals of 3 feet should be left, when each float will have to sustain about 2,632 lbs., the weight of two men and their horses.

The weight of a light 6-pounder and limber complete, with four horses and two drivers, is about 8,000 lbs.; but as these cover about 34 feet in march, they will always be sustained by three floats directly, and further supported by the adjoining two. Three floats could bear this weight, viz.: 2,667 lbs. each, as we have seen; but, to render the operation quite safe, intervals of 15 feet should be allowed between guns in crossing, in order that the weight may be borne by all the floats which are reached by the balks actually pressed upon.

Heavy guns should be unlimbered and drawn across by hand, with long ropes, to keep the men at a distance from them. The weight of a 9-pounder gun and carriage is about 2,856 lbs., which, being more concentrated than any of the other weights here considered, will be most severe upon the bridge.

The rafts are frequently formed along-side of the bank, or on shore, laying the trees in opposite directions alternately, to procure a uniform width,. and fastening them together by cross-pieces of wood, nailed, or tree-nailed to them; or, by lashing the trees together.

The rafts are then launched and floated to their respective situations and anchored, or secured to cables stretched across the river.*

* In the campaign of 1812, the French used, on many occasions, bridges formed of timber rafts. These were constructed separately on shore, on slips; the timber fastened together by cross-pieces, through which treenails were wedged, by the method used in Canada. (Page 226.)

The balks are laid upon beams fastened longitudinally upon the cross-pieces mentioned above; and being 26 feet long, will rest upon three floats, so that any weight standing over one float will be partly borne by the adjoining ones, provided they are not already loaded. Thus, the first set of beams reach from the bank to the centre of the second float; the next set from the centre of the first to the centre of the third; and so on. Blocks of light wood should be put between the cross-pieces and the small ends of the trees, to keep them down to the lower level of the others; and planks, 2 inches thick, lashed or nailed to the beams, complete the flooring.

It is impossible to give rules for the constructions to be observed in the infinite variety of circumstances under which rafts may be applied. The size of the river, the dimensions of the timber, and, most particularly, its specific gravity, must be considered. All that can be said is, that means must be estimated and applied for common occasions, in order that time may not be wasted, nor means thrown away, by applying more than necessary; or danger incurred, by the more fatal error of applying too little.

Eight elm-trees will float about as much as six firs of the same size; and as the spaces between rafts, placed 12 feet from centre to centre, are sufficient to receive two additional trees, the other parts of the construction will answer, and the rafts bear the same weight nearly; but the current will be more interrupted in the latter case, and there will, consequently, be greater difficulty in mooring the bridge.

When it is necessary, therefore, to use as much timber as would, if laid in one row, leave little or no inter-

vals between rafts placed at given distances asunder, the trees should be put in two rows (Pl. LVIII.), by which the current will be less resisted; for, as the velocity of the current is greatest at the surface, the resistance of a deep and narrow raft is less than one of equal area but of greater breadth, and consequently taking up more of the surface of the current. A raft will require two rows of trees at least, unless they are very large, to float as many men as can stand upon it. Suppose trees, 35 feet long, are to be formed into a square raft; allowing 1½ foot for a railing, the remaining space, 32^2, or 1,024 square feet, will be sufficient for the standing of 270 men. It would require eighteen fir-trees, 35 feet long, and about 1.9 feet mean diameter, to make a raft 35 feet square; and these, of medium specific gravity, would only be sufficient to float 51,030 lbs. But a buoyancy of 48,600 lbs. is required for 270 men, exclusive of floor; it would therefore require two rows of trees of this size and specific gravity to make a raft capable of transporting, with safety, as many men as could stand upon it.

Thirty-seven trees, 35 feet long and 3 feet mean girth, would make a raft 35 feet square; but its buoyancy would only be about 26,200 lbs., or about half the weight of 270 men and floor; it would therefore require four rows of these trees to transport 270 men in perfect safety.

Timbers for the formation of rafts are most conveniently put together in the water, on account of the facility of moving them: however firmly the trunks may be united on land, they will unavoidably become loose when the raft is launched. The large and small ends of

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the trees should be placed together alternately, at each end of the raft, in order that the centre of gravity of the raft might be in or near the centre of the figure. Bridges have, moreover, been made with rafts, formed by placing all the butt ends of the trees together at one end, and all the smaller parts together at the opposite end; thus giving to each raft the form of an arch-stone in a bridge. The rafts were arranged contiguously to one another, the broad ends together, in a segment of a circle, with the convexity towards the upper part of the river, by which means the pressure of the current served to keep the whole structure firmly together. The part in the breadth of the river where the current is the strongest, was occupied by a barge or other great vessel, which served to increase the stability of the bridge. The irregular forms of the trees caused intervals to exist, which allowed the current to flow between them with sufficient facility. Some experiments have shown that a raft, composed of trees placed close together, opposes even less resistance to the current, by about one-fourth, than when the trees were fixed at intervals of 3 or 4 inches.

The method practised by the Canadians, in forming the large timber-rafts which descend the St. Lawrence, and particularly the mode of fastening them, may be found useful in constructing rafts for military purposes.

The timber is laid in two or more rows, at right angles to each other. Large holes are bored at the different crossings, with worm augers, through all the timbers excepting the lower row. Strong stakes, each having a wedge applied to a split in the end, are then passed through the upper row or rows, into the lower timbers, and

driven down, by which the wedge, on reaching the bottom of the hole, is forced into the stake, and fixes it securely; the upper parts of the outside stakes are left, to form posts for a railing.

Openings should always be prepared in bridges of rafts, for the navigation of the river, when the bridge is to remain any time, or to avoid destructive bodies. To the timbers in the movable part, and at the standing ends, should be added boats, casks, air-cases, or some other buoyant body, in order to render that movable part more manageable, and to make up, by greater buoyancy, for the loss of support which the disunion of the balks at the opening occasions. Although resorting to this nature of bridge implies a want of boats, casks, or other vessels, yet a few may either be procured or made for this important purpose.

In rapid rivers, the intervals between rafts in a bridge should be considerable, that the current may be impeded as little as possible; but, as the rafts must be large in proportion to the length of floor each has to support, it follows that great intervals incur the necessity of procuring larger anchors, or moorings, and timber of greater scantling for beams. If, therefore, the case is not such as to require great intervals, it would be waste of means and time to use large rafts, and consequently great intervals, instead of having smaller floats, placed nearer to each other, for the passage of like weights.

Expedients for Crossing Streams.

The following instances of the use of rafts, as the most simple and prompt expedients for establishing temporary communications across rivers, occurred in the late war in the Peninsula. Materials for such expedients can never be altogether wanting in the vicinity of habitations, or where any timber of suitable specific gravity can be found; and the ways in which these resources were applied to surmount impediments, which in some instances had cost the enemy much labor and time to overcome, deserve special notice in a work of this description, as instructive examples of what may be effected by ingenuity, talent, and activity, and as a proof of the capacity and valuable services of a corps which no longer exists in a separate state.

In July, 1809, when Sir Arthur Wellesley's head-quarters were established at Placencia, it became necessary to secure the means by which a junction might be formed with Cuesta. Two companies of the staff corps were accordingly sent, with a strong working party, to Baragona, to make a bridge across the Tietar. This river, though deep only on one side at that part, is so wide as to have required fifteen pontoons to form the bridge which the French constructed there some time before, and which, upon retiring to Talavera, they, of course, entirely destroyed.

The officer sent to re-establish a communication across that river could find no other materials with which to effect this than the timber of a large inn and its out-houses, about a mile and a half distant, and some pine-trees that grew in a neighboring wood. The building was there-

fore immediately unroofed, and timber of the following descriptions and dimensions procured from its demolition. Six beams of dry fir, each about 20 feet long and 2 feet square; three or four hundred rafters, about 10 feet long, and 6 in. by 4, in section; six large doors, and 20 running feet of mangers from the stables. The six large beams were formed into a raft, about 20 feet long and 12 wide; the buoyancy of which was therefore about 13,500 lbs. The rafters formed the beams, and the planks of the mangers, the floor. This raft had to support a floor about 30 feet long, to which it was fully adequate; its extreme buoyancy being sufficient to float 60 or 70 men, exclusive of the weight of floor; and half of that buoyancy being not much more than was required for the weights that had to cross it. In the shallower parts of the section, piles were driven into the bottom of the river, and caps of light material laid across; the beams were formed of young pine-trees, 30 feet long, and about 7 inches in diameter. The doors and mangers of the inn, being too thick for the only nails that were forthcoming, were secured to the beams by ribbons formed of young pines, split thus ⊖, which were laid over the ends of the planks, and tied with willow twigs to the outside beams and to the caps of the piles. The raft was made fast to a sheer-line, attached to a tree on one side of the river, and to a stake driven into the sand on the other. A trestle, and two large wooden mallets, made on the spot, were used to set and drive the piles, nearly in the manner shown in Pl. LIX., Fig. 1. On the 18th of July, the army crossed the Tietar by this bridge, and marched by Miajados to Jalayuela.

In Marshal Massena's retreat from Portugal, he de-

stroyed every bridge that he passed over. The second and eighth corps, quitting Santarem on the night of the 5th of March, 1811, fell back by Pernes upon Torres Novas and Thomar, closely pursued by the light division, destroying the bridges in the small river Alviella. The broken bridge at Pernes was speedily repaired by an officer of the staff corps, of great ingenuity and experience, by which the British troops were enabled to follow promptly across this impediment. This was effected by pulling down an oil-mill, using its rafters for beams, and taking the doors of the houses and the materials of the corn-chests (which in Portugal are very large) for planking. With these a communication was thus speedily restored in a very ingenious manner, though neither nails nor tools could be procured.

Pressed vigorously on every line, and driven in succession from Pombal, Redinha, and Cazal Nova, the French continued their retreat, and, crossing the Ceira river, a tributary of the Mondego, took position on the right bank, leaving a corps at Foz de Aronce, under Marshal Ney, to cover the retreat of the troops, and to maintain possession of the left bank until they should all have crossed. By vigorous attacks on the front, combined with skilful movements on the flanks, Ney's corps was driven in such confusion upon the river, that vast numbers of his men were drowned in attempting to ford or swim across, and many were crushed to death upon the bridge. Ney, however, maintained possession of the left bank with a strong rear-guard, till the rest of the troops had passed, and then withdrew and blew up the bridge. On the 16th, Ney fell back from the Ceira, on

the position which Massena, with the main body of the army, had taken behind the Alva, destroying the Ponte Marcella and the bridge at Pombeira on that river.

No timber of sufficient length could be procured to make good a communication across the bridge at Foz de Aronce, by which to cross the Ceira in pursuit of Ney; but a trestle-bridge was speedily established some distance higher up, on which a great part of the army crossed, in the night of the 16th, whilst the light division passed, but with great difficulty, at a ford.

Massena, believing himself secure for some days in the strong position which he had taken between the Alva and the Mondego, began to forage the adjoining country; but a movement made along the heights, on his left flank, obliged him to withdraw from the Lower Alva, when it became of vast importance to establish a communication across that river at Marcella, to get at his front, before any further operation could be undertaken towards the Upper Alva upon his left flank. Materials sufficient to make good the broken arch of the bridge at Marcella could not be procured; and it was therefore found necessary to attempt the passage at some adjoining part of the river, which might be better suited to the very limited means that could be obtained. A narrower part of the stream was therefore chosen, but it was, for that reason, more rapid in proportion, which, together with the great depth, prevented any means of support being fixed in the bottom of the river.

The left bank was rocky, and nearly level with the water; the right was bounded by a stone wall or wharf, 5 feet above the surface of the current. A working party of 200 men was immediately sent into the village,

to collect all kinds of dry timber to make a raft; and, in the mean time, two ring-bolts were let into the rocks at D and C (Fig. 1, Pl. LX.),* and six pine-trees, about 60 feet long, felled and brought to the river by the followers of the army, who were seized on and compelled to perform this service. The raft, A, being ready, one of the trees was laid on and secured to it by spikes and cords—a hole being bored in the other end of the tree, to fasten it by a heel-rope to launch it; and, when this was effected, a strong party held the rope E F, to ease the raft down the stream to G.

The rope was then secured to the ring-bolt at C, and two additional turns taken round the tree and through the bolt, to hold it against the current; a firm footing being thus established in the middle of the river, a second tree was prepared in the same manner, and one end of it slipped along the first beam to G, where it was secured to the raft by a heel-rope. A large cask, procured from the village, being lashed under the other end, the tree and cask were launched into the stream, and shoved out by poles and boat-hooks from I to K, whence, being caught by the stream, they were gently and carefully eased down by the rope *l m*, L M, to the wall O. About thirty men were then sent across in succession on the trees, and by the help of a small tackle, fixed to a post on the wall B, hoisted up the cask and end of the tree and lodged them on the top. Two other trees were then laid parallel to the two former, and the whole

* Crow-bars, pick-axes, or any pieces of iron, let in by a drill into stones or rocks, will answer, if ring-bolts are not at hand; but these are so necessary, that it will always be prudent to have some of the description shown in Figs. 2, 3, Pl. LIX.

planked with doors, chests, and such other articles as had been collected during the time the work was going on.

The work was finished on the 18th. Part of the army immediately crossed; the light division passed at the same time near Pombeira. The right wing, advancing to Arganil, menaced the left of Massena's position on the heights of Moita. Trant and Wilson were moving on the other side of the Mondego upon Fornos; and Massena, by all these combinations, was forced rapidly back upon Celirico and Guarda.

Casks.—After what has been said of the constructions of bridges, of pontoons, boats, and rafts of timber, it will only be necessary to consider casks with respect to their powers of buoyancy, and their formation into floats; the other parts of the construction being completed nearly in the same manner as in the former cases.

The ordinary rule for calculating the volume of casks is founded upon the supposition that a cask is formed of two frustums of cones, with their bases united on the diameter passing through the bung. This rule is expressed, in words, in the following manner:

Add together the area of the circular head, the area of a circle on the bung diameter, and a geometrical mean between these areas; and multiply the sum by one-third of the length of the cask.

As an example, let the bung diameter of a cask be 34 inches, its head diameter 27 inches, and its length 50 inches, outside measure: then π $(=3{\cdot}1416)$ being the area of a circle whose semi-diameter is unity,

$$(13{\cdot}5)^2\pi+(17)^2\pi+13{\cdot}5\times17\times\pi=36691{\cdot}8$$

is the volume, in cubic inches (=21.233 cubic feet).

Multiplying this number by 62·5 (the weight, in pounds, of a cubic foot of water), the product (1,328) is the weight, in pounds, of the water displaced by the cask. But the figure by whose revolution that of a cask is described, having one side curved, this rule gives a volume which is too small. * * * *

In order to avoid the labor of calculation, the following table has been computed for such casks as are commonly used in this country; it will show, by inspection, the buoyancy required:

TABLE.

No.	Diameter.		Length.	Weight of Cask.	Weight of water displaced.	Weight borne when immersed.
	Bung.	Head.				
	in.	in.	in.	lbs.	lbs.	lbs.
1	15	14	17	26	108	82
2	16	14	16.5	30	115	85
3	17	15	18	32	140	108
4	20	18	22	47	191	144
5	23.3	19.5	24.75	58	345	287
6	24	22	27.5	83	436	353
7	28.1	23.4	33.5	101	680	579
8	29.2	25	31	102	696	594
9	28	24	35	115	724	609
10	29.5	25.4	35.5	128	817	689
11	31	27.5	38.5	140	997	857
12	34	31	35	122	1124	1002
13	30.9	24.7	51	155	1232	1077
14	33.8	24.6	53.25	159	1416	1257
15	35	28	47	159	1430	1271

When casks of various sizes are collected to make a bridge they should be classed, and each raft formed of vessels of nearly equal dimensions.

As casks are not subject to be filled, like boats, or other open vessels, and their buoyancy may be easily calculated with sufficient accuracy, it is not necessary to allow much excess in determining the number of casks required to form a raft; but they should be placed so that the bung-holes may be easily got at, to pump out any leak-

age; for which purpose small pumps should be prepared, and a hole bored through the floor, above each cask, to receive them when necessary.

A buoyancy of about 5,800 lbs. will be sufficient for rafts, placed at the distance of 12 feet between their centres, for a bridge for field artillery, infantry in files, and cavalry by twos, allowing about 1,980 lbs. for the weight of 12 feet of floor, there will remain a buoyancy of 3,820 lbs. for each raft.

The weight of infantry, crossing in file, is	2,160 lbs.
Ditto of cavalry, by twos	2,632 "
The proportion of the weight of a light 6-pounder, which each float will have to bear	2,667 "
A 9-pounder gun and carriage, without limber, is about	2,856 "

But, leaving intervals between guns, this will partly be supported by the adjoining rafts. * * * *

Rafts of casks may be reckoned very useful expedients to complete a bridge, when the pontoon train is insufficient. Large casks should always be preferred to small, particularly in case of land carriage, because there will be less weight to transport than for an equal power of buoyancy made up of smaller casks; this is shown in the table.

It will more frequently happen that this expedient is applied to make detached rafts, than to form a connected bridge. For these, frames of suitable superficial area should be prepared, and lightly planked over, and as many casks put under each frame as may be necessary to give the requisite buoyancy.

In mountainous and other difficult countries, rafts

formed of casks, or other small, close vessels, may be highly useful. These, together with the necessary planks and beams, may be carried on horses, mules, or other beasts of burden, or even by hand, where carriages can neither be procured nor used. For such cases, this is, perhaps, one of the most valuable expedients that can be resorted to, for the passage of rivers in desultory operations. With armies in general, empty casks, sufficient to make a considerable raft, may always be supplied by the Commissariat and other departments.

The Russians, in their wars against the Turks and Tartars, have always been obliged to carry across the deserts, supplies of water sufficient for several days' consumption. The casks, after having served for this purpose, were reserved for constructing rafts and bridges. In General Münnich's campaign in 1736, and in several subsequent operations, this simple expedient was adopted: Each company took with it a large barrel of water for its own use; and, in order to make the empty vessels available to the other purpose, eight or ten planks were likewise carried by the men, in turns. In this way the Russians have frequently, and very readily, crossed large rivers by means which had been provided for another essential use; and from these facts the author has been led to suggest that casks, which may have become void, may thus be turned to great profit, and often prove a very valuable resource. Casks, being lighter, displace less water than any sort of timber-raft carrying the same weight; they are, therefore, more buoyant and manageable than rafts formed of timber, and may, either wholly or in combination with timber, be extremely serviceable.

Air-tight cases, made of light wood and other materials, are likewise useful expedients for constructing rafts; and may also be used either exclusively, or to give buoyaney to other floating bodies, as recommended by M. Folard.

In the French *Aide-Mémoire*, p. 1253, we find the following mention of a raft or bridge of air-tight cases made of light planks, proposed by an engineer of Cambria, named Hermann, in 1719. The cases were each 5 feet long, 1 foot deep, and 1 foot broad; divided into four compartments, by interior partitions, for the double purpose of preventing one leak from filling a whole case, and of giving it strength to resist the outward pressure. Four of these cases lashed together formed one raft. Each case weighed about 75 lbs. To make a bridge for infantry,—the first case being put into the water, and pushed off, to make room for another, the second was launched, and connected with the first by clamping together the ends of the beams or balks attached to each. Both cases, so connected, were then pushed outwards, to give place to the next set; proceeding in this manner, the communication was prolonged till completed, and the rafts were sustained against the current by ropes affixed to the banks. The weight of a raft, composed of four cases of these dimensions, was about 300 lbs. The weight of water displaced at their greatest immersion being about 1,250 lbs., the buoyancy of each raft was therefore about 950 lbs., sufficient only to support infantry marching in single file.

Excepting for convenience in transport, it would be a waste of means to provide small cases like these, for constructing a raft or bridge; since a boat, capable of dis-

placing a much greater quantity of water than the raft formed of four cases, might be made with fewer materials; all small vessels are made up of more material than larger ones, in proportion to their volume.

Twenty of these cases put together would form a raft, 20 feet long, 5 broad, and 1 deep, having a buoyancy of about 4,750 lbs., which is nearly equal to a large tin pontoon, sunk 11 inches. Rafts such as these, placed 5 feet asunder, would therefore suffice for a bridge for cavalry in single file, for infantry in double file, and for artillery unlimbered

A slight frame of deal, 20 feet long, 2 broad, and 1 deep, covered with tin, would form a very buoyant vessel. Such cases, laid parallel to each other, at 1 or 2 feet asunder, connected by balks, and covered with light planks, would form a safe bridge for infantry, and an excellent raft might be made with them; for, as has been observed with respect to casks, not being liable to fill, they may safely be loaded, till nearly immersed; they are also more portable, and less liable to be damaged by sun-heat or drought, than vessels covered with planks.

When, in preparing materials for rafts, timber is not abundant, and there is time to convert a portion of it into planks; or, if these can, in any way, be procured, it will be found more economical of means to construct some airtight cases, than to use the materials in bulk. A piece of fir timber, 1 foot square, and 25 feet long, will float about 703 lbs.; cut into inch planks, it would furnish stuff sufficient, nearly, to make three cases of the same size as the solid piece; for, to complete these, it would only require, in addition, six pieces, 1 foot square for the ends, with three pieces to each case, for interior partitions, to

give it strength and safety. Thus a case of this magnitude would float 1,212 lbs.

Therefore, three cases will float	3,636
Deduct buoyancy of the solid piece . . .	703
Difference of buoyancy, in favor of the three cases,	2,933

Inflated bags, made of animal skins, displace great volumes of water, compared with their weight, and may therefore be considered useful expedients for forming rafts, or for giving additional buoyancy to those formed of other bodies. The Greek army in the pay of Cyrus, crossed the Euphrates on rafts, formed of skins stuffed with hay. (Anab., lib. 1., cap. 4.) Alexander adopted this expedient, to pass the Oxus. (Arrian., lib. iii., cap. 29.) Livy tells us (lib. xxi., cap. 23) that some of Annibal's Spanish infantry passed the Rhone by swimming, with the assistance of inflated leathern bags; and Cæsar mentions, that the Spanish and Portuguese light infantry were in the habit of passing rivers in this manner. (De Bell. Civ., lib. 1.) Rafts of inflated leathern bags are, to this day, used on the Tigris and the Euphrates. M. de Thévenot gives an interesting description of the construction of these rafts (*kelecs*), in one of which he descended the Tigris from Mosul to Bagdad, a distance of about 190 miles. The kelec is composed of twenty rows of inflated bags, each row being formed by lashing thirteen bags to a pole. Over these, placed about 2½ feet distance from each other, the floor is laid, and the merchandise placed upon it; leaving a clear space, about 2 or 3 feet wide, on the outside. Kelecs are generally about 24 feet long and 18 wide. The skins are kept constantly wet, to prevent the air from escaping;

but it is, nevertheless, necessary to inflate them afresh daily.

For a detailed account of the rafts, consisting of logs of timber and inflated skins in use on the rivers of Western Asia, see Colonel Chesney's Expedition for the Survey of the Euphrates and Tigris, vol. II., chap. 20.

M. Folard appears to have taken from some such practices, the idea of furnishing corps of light cavalry, with leathern sacks, such as are used in wine countries for holding wine; two sacks to be fastened to each saddle, and inflated when required. In this way, Folard observes, "cavalry may pass rivers, however wide and rapid they may be, without risk or difficulty."

A proposition was submitted to the Institute of France, a few weeks ago, by Captain Williac, for making rafts for bridges of inflated bags, formed of animal skins sewed together, or of canvas bags lackered over with a solution of gum-elastic (india-rubber), by which the seams and pores may be made impervious to water. The bags with which the experiments were made were of an elliptical shape, 6 feet long, 2 feet wide in the centre, and 2 feet deep. The upper surface was fastened to a frame 7 feet long, and 2 feet 3 inches wide, with sides a few inches high, forming, consequently, a shallow, light case, in which the bags, when not inflated, might be packed for travelling. The contents of each bag were about 18½ cubic feet, capable, consequently, of displacing about 1,190 lbs. of water; but, allowing for compression and imperfect inflation, it may be rated at 1,150 lbs. To inflate the vessel, two or three men, standing on planks attached to the lower surface of the bag, lifted the frame, by which, the sides of the vessel being stretched, the air

rushed in, to fill the interior space, through a cock or spigot; and, in this way, without the aid of bellows or other machine, the vessel was filled in a few seconds. The weight of each vessel and frame was about 70 lbs. A mule, Captain Williac observes, can, consequently, carry four; or fourteen, with their appurtenances, may be transported on three carts. To form a raft capable of bearing as much as a bateau, seven of these vessels were put together; three alongside of each other for the centre of the raft, and two at each end.

There is no doubt that this expedient might be resorted to, with advantage, upon many occasions, in the absence of other means. In Spain, where bags of animal skins are commonly used for containing wine, this was one of the expedients for passing rivers, upon which the author was prepared to act, when serving with a Spanish army unprovided with any sort of bridge equipment. To make a raft of these, all that would have been required was to prepare a light frame of timber, with sides about a foot deep, and to place under it as many inflated skins as might be necessary for the buoyancy required. Expedients of this kind may frequently prove useful in enterprises of a desultory character. The bags should be small and numerous, to multiply the chances against injury by shot-holes; for a single musket-ball penetrating a bag, instantly deprives it of all its principle of buoyancy. This is a danger to which rafts, formed of inflated skins, were not exposed in the time of the ancients, but is now an insuperable objection to their general application.

Wherever troops are regularly supplied with fresh meat, or cattle abound, a sufficient number of animal skins

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may soon be collected, to form, in this way, a considerable raft. The following experiment was made with an ox-hide, trimmed into a circular shape, of about 5 feet 6 inches in diameter. The skin was drawn together at the edge, and firmly bound round a tube made of alder-tree, having the pith removed; and a piece of leather was nailed upon the inner end, as a valve, to prevent the air from escaping. The vessel was inflated by a common hand-bellows, and floated 300 lbs.; and, without any application to close the pores of the skin, remained nearly fully inflated for five hours; at the end of twenty-four hours it was still found capable of floating 150 lbs. The weight of the skin was 45 lbs., so that, by this expedient, great power of flotation may be packed in small space, and easily transported. Skins may be preserved for a considerable time by common salt; and, if covered with a solution of gum, or any glutinous substance, more particularly at the part which corresponds to the back of the animal, where skins are always most porous, they will retain the air for a very considerable time. By means of the wooden tubes, the skins may be re-inflated in succession at any time, without withdrawing them, by merely turning up the tube, taking off the lashing, which, as a precaution, should be made to close the vessel effectually below the valve, and then using the bellows, as before.

A good portable pontoon may be formed of tanned hides, applied as a covering to a slight frame or skeleton of wood, which, for transport, may easily be taken to pieces. Models of such vessels, and of the basket-boats of India, as well as the canoes of the ancient Britons, may be seen in the Royal Military Repository at Woolwich,

where, indeed, every thing relating to the theory and practice of this important department for effecting and facilitating military operations is arranged, taught, and practised, in the most able and useful manner, under the direction of a very experienced and distinguished officer.

A usual method of crossing rivers in India is by *basket*-boats. Wilks, in his account of Southern India (vol. II., page 174), justly observes: "This simple method of crossing wide and unfordable rivers is recommended to military practice, for the facility with which the materials may almost everywhere be obtained." The frame-work, or basket, is constructed of split bamboos, and the covering formed of half-dressed hides. The method of constructing basket-boats, as described in Moore's "Narrative of the Operations of Little's Detachment," page 122, is very simple. A number of pieces of split bamboo are laid on the ground, crossing each other near their centres, and fastened together with leather thongs. The ends of the bamboos are then raised to a sufficient height, fixed by stakes at due distance from each other, and then bound together by slips of bamboo, introduced, alternately, over and under the ribs, as they may be called, beginning from the bottom, and working upwards, till the skeleton is completed. The ends of the ribs, above the intended height or depth of the basket, are then cut off, and the stakes removed; the frame is then turned over, and covered with hides, sewed together by leather thongs. The dimensions usually given to these vessels are, 15 feet in diameter, and 3 feet deep. A basket-boat of this size is sufficient to carry thirty men with their equipment, or any field-gun, carriage, or tumbrel, embarked singly; when bullocks or

cavalry horses are to cross, they are tied by the heads to the baskets, by which they are conducted across the river, either by rowing or poling. In the campaign of 1800, under the Duke of Wellington, then Colonel Wellesley, this expedient was resorted to with great success. Some rivers in his front had become unfordable by heavy rains, but the difficulty was soon got over, by means of some basket-boats which were constructed and carried by the pioneers of the army. "It was surprising," says the author's informant, "what efficiency even this simple expedient gave to our enterprises, on a service, and under circumstances, which particularly required rapidity of movement." And this campaign finished, by the enemy being driven into a *cul-de-sac* between two rivers, which he had no means of crossing; and where he was completely destroyed, in consequence of Colonel Wellesley having been enabled to pass those rivers which crossed the line of his march.

The chief defect of the basket-boats, described as above, consists in their shape; but the mode of, and materials used in, their construction are particularly adapted to military service, as substitute expedients, under any such circumstances. A framing of split bamboo combines toughness and strength with lightness, in a great degree. A covering of hides is less liable to injury from sun-heat or from strains, whether in transport or flotation, than planks, and much more easily repaired than these or metal. These qualities of the materials of which common basket-boats are formed, are obviously such as may be applied to make any given form of vessel, retaining the advantages of convenience in portability, whether by hand or by beasts of burden.

Nothing more appears to be necessary to effect this than to work these materials into a boat-like shape.

The canoes of the North American Indians, which are used on a large scale by the Canadian *voyageurs* employed in the service of the fur companies of Canada, to penetrate into its remotest regions (which is effected partly by *portage* and partly by navigation), is an abundant proof of the practicability of making vessels of great capacity with such light materials that they may easily be carried by the men whom, in turn, they transport. These vessels, though formed of slight ribs or strips of tough wood, and covered only with bark of the birch-tree, are sometimes made large enough to carry twelve or fourteen men, and a considerable quantity of merchandise besides. * *

Substitutes for Anchors.

Having treated of the various expedients by which the passage of rivers may be effected, when neither pontoons nor any other regular vessels can be transported or procured, it is intended to conclude this section with some notice concerning the expedients which may be resorted to as substitutes for anchors.

One or two spare wheels may be made very serviceable in constructing a substitute for a grapnel. The tire and fellies being shaken off, the spokes will act as teeth. Those that are intended to bear, or the whole, if necessary, should be faced, by nailing to each a triangular piece of hard wood (Fig. 3, Pl. LX.). An axle-tree or a spar of strong, tough wood, may form the shank; braces of tough wood should be attached to the spokes, and brought together at the end of the shank (Fig. 4), to

strengthen the spokes, and to contain stones, by which to force the teeth into the ground.

Two wheels, thus fitted, and set upon the same shank (Fig. 4, Pl. LX.), would form a very secure mooring. In this case, the stones should be packed round the shank which passes through the naves, and pieces of wood laid from nave to nave, passing between the spokes, as represented by the dotted lines in Fig. 4.

Two old or spare wheels, placed face to face, their fellies well lashed together, and the space between the wheels loaded with stones, would also form a secure mooring. The strength would be increased by fixing a strong stake through the axle-holes, with its point projecting about a foot below the bottom of the mooring, and by a few tough stakes, set obliquely through the interior spaces between the spokes; these should point forwards, in the direction of the strain, that they may be forced by it to enter and bed themselves in the bottom of the river. Such moorings as this and the preceding should be eased down to their place by ropes from boats or rafts.

A harrow with lengthened teeth, loaded with stones, and eased down to the bottom of a river, would afford a good *holding* in soil of much tenacity. This may be applied on a large scale, by fastening together two strong beams of timber, 2 or 3 feet asunder, and setting stakes of strong, tough wood into them; or the teeth may be formed of the iron tires of a pair of wheels; or other iron, transformed into curved teeth. Such a frame, loaded with stones sufficient to sink it, and eased down to its place, may be further bedded in the bottom, by throwing or placing heavy stones upon it; or, if the water be not

too deep, by driving stakes, previously set through the frame, into the bottom of the river.

Piles, wooden grapnels, cases or gabions filled with stones, are the most simple substitute means by which rafts or flying bridges may be moored. If large blocks of stone can be procured, there is no better substitute for anchors: and the only difficulty in resorting to such means, is that of removing and placing them in the river, which, however, may be effected by some of the means with which pontoniers should be very conversant. Ring-bolts should be set in the stones used for moorings; and this, indeed, is indispensable, where hempen cables are used, because these would soon be chafed through by the edges of the stone. The ordinary way of fixing ring-bolts is to set them by melted lead; but then they cannot easily be removed. An ingenious and simple method of fixing ring-bolts in stone, from which they may be taken out with great facility, is shown at Fig. 2, Pl. LIX. A dovetailed mortise is cut in the stone, large enough to receive the three pieces of iron A C, B D, and G. The dovetailed pieces are first placed in the mortise; the centre-piece G is then set between them, and the shackle E fastened to the three by the bolt F, which passes through them all. A few such ring-bolts should always be provided, together with any other stores and materials which may be furnished for the contingencies of service. But ring-bolts, set in this way, cannot be removed without weighing the stone, to which the chain is attached. When, therefore, heavy stones are to be used as moorings, or when there may be any other occasion for lowering into, and laying them in deep water, the central part (A, Fig. 3) of the three

pieces which are to be let in to the dovetail space, should have the ring and chain attached to it, and be made of a dovetail; and when set in the stone, two oblique pins, or prisms, *e f*, inserted, one on each side, to fill the remainder of the space. These prisms having rings in their heads, ropes or chains are attached, by which the pins may be pulled out at pleasure, and thus disengage the ring-bolt without weighing the stone.

If stones large enough to form moorings cannot be procured in single blocks, double moorings formed of two stones, connected together by a chain or strong rope, may be used; and these, indeed, are preferable, because they are more secure than a single block of nearly the same weight, and require less labor and power to remove and place them.

Pile moorings may also be used with great advantage. Piles for this purpose should be driven obliquely, and placed behind each other, in two or three rows. The face of every pile should be braced diagonally, and as low as possible, to the back of that which stands before it; for which purpose notches or grooves should be cut in the backs of the piles that are thus to sustain others, and strong cleats nailed on them, at the bottom of the grooves, so that the braces may easily be set and fixed. A chain should be passed round the whole, and suffered to sink, by which the strain may be applied to the piles at the bottom of the river. To secure the mooring from being injured by drifting matter, the heads of the piles should then be cut off as low as possible under the surface of the water, and stones thrown or lowered into the interior space formed by the piles. These may easily be confined therein by strong planks, or rough cases

made to fit between the piles, and sunk by the stones packed in them.

A fisherman's anchor (Fig. 4, Pl. LIX.) is made of two pieces of timber, A B, C D (the former curved), of length and strength suited to the power required; these pieces are let into each other at right angles, and tree-nailed together. Four tough pieces of wood, E F G (the other not seen in the figure), are wedged firmly into the cross-pieces, at the posts 1, 2, 3 (4 not seen), united as at I, at a proper distance, and there worked into a loop, or attached to an iron ring. One or two stones of a shape and magnitude to fill the spaces, S S, contained within these four shanks, should be placed therein before they are joined. This very valuable expedient may be applied on almost any scale; and the author has seen such grapnels supplying the place of anchors, efficiently, for vessels of fifty or sixty tons, in remote parts of Newfoundland. A capital grapnel may be made of two or three large-sized pickaxes, such as are commonly used in quarries, or for other heavy works, set upon the same shank, with the blade of a shovel fixed upon each branch. Two large pickaxes, thus fitted with flukes, may be put together, so as to form an anchor resembling the double anchor, by fastening them firmly, parallel to each other, to two crowbars, as represented by Fig. 5, Pl. LIX., uniting the two shanks (which should be longer, stronger, and, if possible, heavier than the ordinary handles) at K. Should the anchor come to the bottom on the ends, *c c*, of the uniting pieces, these, not being set fair with each other, would, together with the strain upon the cable, insure the canting of the anchor to the proper position; but should this be doubted, it may

be placed by ropes in the right way. No materials are more susceptible of conversion to such purposes than these implements. They may be procured in all inhabited cultivated countries; and if not sufficiently strong and long in the arms, the picks may easily be re-enforced and lengthened. The weight of the anchor (Fig. 5) is about 1 cwt. To give the substitute anchor greater weight, crowbars, if procurable, should be used for the shanks, and for the pieces *c c;* if these cannot be had, timber may be used, and weight given by packings of stones. At first sight, it appears that the difficulty of procuring anchors is one of the most formidable impediments in devising means for passing large rivers by floating bridges made upon the spot; and military history shows that many serious accidents have occurred from the insufficiency of anchors, even with regular equipments; but the author is persuaded that such men as those Engineers and Staff Officers whose eminent talents and services in these departments he has endeavored to describe, would, under any circumstances, find this the least difficult part of such undertakings, and always be prepared to supply any want of this description.

The practical efficacy of all these expedients will depend very much upon the nature and consistency of the bottom of the river, at the particular parts at which they may be placed, and consequently upon the degree of intelligence with which choice may be made of those parts which are most likely to afford good holding-ground; for the author has shown that, by selecting a proper locality, and even a particular part of the section at the place chosen, banks, more or less deep and tenacious, may be found in all rivers; it will therefore

rest with the persons applying these expedients to avoid laying anchors or moorings, whatever they may be, in parts from which the current, moving with great velocity, will have swept off all the finer particles upon which good holding-ground depends, and to prefer those places where the stream, diverging from the main current, loses part of its celerity, or forms eddies; and where, consequently, the water deposits the smaller particles, which it had the power to move or keep suspended when flowing with greater velocity. It may be that the best holdings are neither near nor directly above the boats; but it is much better to get an oblique but firm holding, either upon a bank in the river, or on the side of the river, than to lay anchors, strictly according to rule, immediately and directly above the vessels respectively, without considering or ascertaining whether the bottom there may be favorable or otherwise to the stability of the bridge.

Bridges on Trestles, on Piles, and on Carriages.

A bridge supported on trestles possesses these advantages over boat or raft bridges: that it may be very readily constructed with timber which may almost everywhere be procured, and that it may easily be laid in shallow water; but such a bridge in deep, muddy, or fluctuating rivers, is subject to casualties which render it an insecure and uncertain description of communication. The legs do not usually, without repeated adjustments made in their length, find level standing in the bottom of the river, and even though in appearance solidly placed, they are liable to sink unequally when the bridge is loaded; and any subsidence of one trestle

obliquely, occasions strains in the superstructure, by which the bridge may be suddenly broken.

The chief advantage of this expedient for crossing rivers, consists in its simplicity and portability. Materials sufficient to make a good trestle may be carried by one mule; and if these be previously fashioned, fitted, and the parts numbered, the trestles may soon be put together, and a bridge readily formed of them. Trestles prepared in this way, beforehand, to be conveyed with troops, should have fastenings of iron bolts and keys, that they may be speedily set up, and easily taken to pieces; but when trestles are made for application upon the spot, and there to remain, wooden pins may be used. In either case, the principle of construction shown in Figs. 6 and 7, Pl. LIX., should be observed. The length of the legs will depend upon the depth of the water; but for general use, six feet may be allowed. The interior faces of the legs should be notched to fit underneath the head, or ridge-piece, which will then be solidly supported. The strut, or inclination of the legs, should be such that the breadth of the base upon which the trestle stands be equal to about half its height; and the legs should likewise incline longitudinally, strutting one-sixth their height. Small trestles, used for slight bridges, should only have four legs, and require no other additional support for the ridge-piece than what may be given to it by diagonal braces from the legs; but for great weights, it will be proper, after the trestle is placed, to apply on each side of the centre of the ridge-piece, additional legs, driven by pile-engines as far as possible into the bottom of the river, and then nailed to the ridge-beam. The reason for not adding these as an additional pair of legs to the

trestle, before it is placed, is, obviously, the additional difficulty there would be in adjusting six points of bearing to the bottom of the river. Wooden pins should be inserted into the heads of the trestles, or cleats nailed on them, to form spaces to receive and keep steady the beams; and gang-boards or curb-pieces should be firmly lashed to the outside beams, and to the heads of the trestles, in order to connect and consolidate the whole.

The heights of the trestles should be sufficient to carry the floor of the bridge above the level of any probable rising of the river; they should not be placed nearer to each other than twelve feet, in order to allow space for drift timber, etc., to pass through, and to impede the current as little as possible. If good timber for beams can be procured, and abundant means of transport provided, strong trestles should be used, and intervals of at least fifteen or twenty feet allowed.

Comparing the quantity and portability of the materials in a bridge of trestles, with the requisites for other bridges, the convenience of this construction, under certain circumstances, will appear to be very great. Suppose an unfordable, but not very deep river, two hundred feet wide, having a firm, sound bed, is proposed to be crossed; it would require twenty pontoons to make a bridge over a stream of this magnitude, whereas, with beams twenty feet long, nineteen trestles or bays will be sufficient; and trestles may easily be transported, when neither bateaux, pontoons, nor carriage-bridges can be conveyed without great difficulty; but, unless the trestles can be effectually secured against any flood that may happen, this would be a very objectionable sort of communication.

In laying the bridge, the first trestle is placed at the intended distance from the bank, and perpendicular to the proposed line of the bridge. The first set of balks are then laid, one end of each resting on a plank laid on the bank, the other ends resting upon the trestle, and the floor is completed to the first trestle. To place the second trestle, if the river is so deep that this cannot be done by hand, lay two beams in the position A B (Fig. 7, Pl LIX.), upon the head of the first trestle, with their ends resting on the bottom of the river, at the place where the second trestle is to stand; lower the trestle down this inclined plane to its proper place, and push the head outwards, till the trestle is upright. If it then rock or totter, withdraw it, and readjust the legs to correspond better with soundings, more correctly taken, of the bottom of the river, at that part. But trestles may be more conveniently placed from small rafts, formed of boats, or any buoyant bodies, by which much trouble and difficulty may be avoided, and time saved, from not being obliged to wait till the floor is completed to each trestle, before another can be laid. A small raft of two boats was used in this manner, for laying the trestle-bridge across the Agueda. Monsieur Répicaud, an officer of French Engineers, suggested that rafts, sufficient for this purpose, may always be made of the beams and planks which are to form the further end of the superstructure, because these are not required till the last.

If the current be strong, a cable should be stretched across the river, on each side of the bridge, in the plane of its floor, and the trestles lashed, in succession, to them. This will very much facilitate and insure the

laying of the floor; but in a very strong current, it will be difficult to retain trestles in their proper places, before the weight of the floor is put upon them, unless they be previously loaded in some manner; this would not only immediately establish them, but give stability to the bridge that is to be laid on them.

On the retreat from Moscow, in 1812, Napoleon and the wreck of his army crossed the Beresina on two trestle-bridges.

The Russians having cut the bridge at Borisow, and being in position, in great strength, on the right bank of the river, it became impracticable for the French to effect a passage there. It was generally expected that Napoleon, checked at that point, would endeavor to pass the river below Borisow; and, accordingly, the Russians directed their attention and movements to the Lower Beresina, whilst Napoleon turned, with infinite ability, to attempt the passage near Weselowo, about four leagues higher up.

General Eblé, of the Engineers, who, from the beginning of the campaign, had made all the arrangements for the equipment and construction of military bridges, was specially charged with the important duty of providing for the passage of this river; and he discharged that duty with a degree of forecast and ability, to which, certainly, Napoleon owed his escape, and the wreck of his army its safety.

General Eblé began to prepare, at Smolensko, for the difficulties which he foresaw in this operation. He formed, with every care, a train sufficient for the transport of all the tools and stores that might be required; and further, to provide against casualties and accidents,

every man belonging to the companies of pontoniers, was obliged to carry from Smolensko a tool or implement of some kind, and a proportion of nails. Fortunate was it for the army that he did so; for such was the difficulty in bringing up the carriages containing stores, that only two forge wagons and six caissons of tools and nails could be preserved. To these the general added a quantity of iron-work, taken from the wheels of carriages that were abandoned on the march. Much was sacrificed to bring off these valuable materials for making clamps and fastenings, but, as Ségur observes, that exertion "*sauva l'armée.*"

The breadth of the Beresina at Weselowo is about 100 yards; the greatest depth, from 6 to 7 feet; the bottom muddy; the current moderate, but much loose ice was drifting down. The right bank is usually very marshy and soft; but the frost had hardened the ground, and made it practicable for carriages to approach the river.

The preparatory works were commenced at about five P. M., on the 25th. Timber was procured from the demolition of houses. The height given to the trestles varied from 3 to 9 feet, according to the part of the river in which they were placed. The length of the ridge-beam was 14 feet. Twenty-three trestles were designed for each bridge, and, consequently, twenty-four bays, or intervals, of about 13 feet. Trees about 16 or 17 feet long, and from 5 to 6 inches in diameter, were felled for beams, and applied in the round, there being no time to square them. For the superstructure, or roadway of the bridge, intended for the artillery and other carriages, round timber, from 15 to 16 feet long, and from 3 to 4 inches in diameter, was collected. For

the flooring of the bridge for the infantry and cavalry, old planks, about 7 or 8 feet long, and 5 or 6 inches broad, and half an inch thick, to be placed in three layers, were torn off the houses.

At daylight, on the 26th, it was announced to Napoleon, that the division Tchaplitz had moved from its position on the other side of the river. Napoleon immediately ordered some troops to be thrown across, and the two bridges to be commenced. Both were immediately begun; and, at the same time, some cavalry, each dragoon taking an infantry soldier behind him, swam across; whilst, by three small rafts, each capable of carrying about ten men, three or four companies of light infantry were likewise thrown over; these, in a short time, cleared the right bank of the river of the Cossacks, who still hovered about. Great difficulty was experienced in placing and keeping the trestles steady, until the floor could be laid, and, by its weight, fix them. No small boats could be had to facilitate the work; and the frost was so severe, that many of the pontoniers, who were obliged to remain in the water throughout these operations, nearly perished with cold. At about one P. M., on the 26th, the bridge for the infantry and cavalry being finished, the divisions of Le Grand and Dombrouski, amounting to about 7,000 men, crossed; and an 8-pounder and howitzer, with their wagons, and some others, with musket ammunition, were taken over; in doing which, it was necessary to observe the greatest circumspection and caution. The bridge destined for carriages (the construction of which was suspended for about two hours, in order to finish the other the sooner) was completed at about four P. M., and the artillery

and other carriages immediately began to pass. The roadway of this bridge being composed of round timber, the movement of the carriages on so rough a surface, and the pace of the horses, which, notwithstanding the orders that had been given to the contrary, were permitted to trot, caused the most violent shocks to the bridge. The trestles sank, unequally, in the muddy bottom; great undulations in the superstructure, and inclinations of the trestles to either side, ensued; and these occasioned still greater strains. The feet of some of the trestles separated and three fractures in the roadway took place. Fresh beams were laid, but soon afterwards three trestles broke. The pontoniers resumed their work, and at eleven o'clock, the bridge being again practicable, the carriages recommenced crossing. On the 27th, at two A. M., three trestles, in the deepest part of the river, gave way; the pontoniers immediately set about repairing the disaster, but this proved a very difficult operation. It was effected, however; and the communication being re-established, the movements were resumed at about six A. M. Again two trestles broke, but they were repaired after about two hours' labor; the movements continued, and thus a small portion of the vast material of the grand army was saved.

The trestles of the bridge on the right, being only for cavalry and infantry, did not give way; but the thin planks which formed the roadway, having suffered much from the use which had been made of them, as coverings to the houses from which they had been torn, could not be solidly fixed, and were constantly getting deranged, splitting under the horses' feet, or breaking into holes. To obviate this as much as possible, the floor was strewed

with tow and hay, and the covering frequently renewed and readjusted.

When the Imperial Guard began to move, the stragglers dispersed in the surrounding woods and villages, who had not taken advantage of the first night to cross the river, now rushed from all sides, and flocked to the river in one dense and confused mass, which soon choked up the narrow entrances to the bridges. The foremost, impelled by those who followed, were driven upon the guards and pontoniers, who were endeavoring to keep a passage open for the troops. In repressing these crowds of fugitives, many were trodden under foot in the *mêlée;* others thrown upon the floating ice; and great numbers, unable to regain the bridge or to reach the shore, perished in the river. The efforts of Napoleon and his officers to re-establish order were unavailing. So great was the confusion, that force was necessary to clear a passage even for the Emperor, who crossed at about two P. M., with about 6,000 of the guard under Ney. The troops continued to pass till the morning of the 29th; but multitudes of stragglers, benumbed with the cold, were unable to avail themselves of this last opportunity; and, about eight in the morning, General Eblé, seeing the Russians advancing, was obliged to set fire to the bridges, leaving vast quantities of ammunition, artillery, and baggage, thousands of men, and many women and children, to the mercy of the enemy and to the rigors of the climate.

The manner in which a communication across the Elbe at Dresden was restored, in 1813, is an interesting and instructive proof of the vast scale on which trestles may be applied, to make good a temporary communication across broken arches.

The French, in retiring from Dresden, destroyed two of the principal arches of the great bridge. The Russians resorted to extensive and difficult applications of carpentry to repair this breach, which, being of considerable span, required a commensurate supply of large timber, and much labor to make good. On the retreat of the Allies, after the battle of Lutzen, the Russians burnt the work by which this communication had been restored; and thus a formidable impediment was made to the movement of the enemy. Upon the arrival of the French troops on the Elbe, Napoleon ordered a bridge of rafts to be thrown across the river below Dresden, and that every exertion should be made, at the same time, to restore a passage across the fractures in the stone bridge. Large trestles were first proposed, as the most expeditious and simple method of effecting this; but the project was rejected, on account of the depth of the breach, and, consequently, the great height which it would be necessary to give to trestles if laid in one story, and the difficulty and instability there might be in applying them in two tiers. It was, therefore, determined to resort to the same mode of construction as that which the Russians had recently adopted to re-establish that communication; whilst the bridge of rafts, constructing below, might serve for the passage of any troops it might be necessary first to send across. But the bridge of rafts not having been found to answer, and the Russians having evacuated Nieustadt, it became of vast importance to Napoleon to establish, as soon as possible, a secure communication, by repairing the great bridge; this brought again under consideration the project which had been originally suggested, and which, with some

alteration, it was now resolved to adopt. The proposition for applying two stories or tiers of trestles had been rejected on account of the instability of such a scaffolding; it was, therefore, determined to construct trestles of dimensions sufficient to make good, in one tier, a communication level with the roadway of the bridge. The trestles were about twenty-six feet in vertical height, and were formed of trees in the rough, but strongly put together. The beams were likewise made of trees recently cut and unbarked; and planks for flooring were found in the boat-yards at Dresden. The trestles were laid in the following manner, in succession: The first, being carried to the brink of the broken arch, was thence lowered down an inclined plane formed by beams, and then hauled, by people on the other side of the gap, to the upright position, preventer-guys being used to ease the operation; the legs of the trestles were previously cut to correspond with the inequalities in the bottom of the river, which were accurately determined by taking levels or soundings. The ruins of the broken arches, which had fallen between their piers, formed excellent solid foundations upon which to place the trestles; but there was a good deal of difficulty in adjusting the legs to a firm footing on the asperities of this dike of ruined masonry; and as the least inequality in bearing at the base would obviously have operated with vast force, at such an elevation as that to which the superstructure was raised, to destroy the whole by its own weight, so the greatest nicety was required in making that adjustment. When the first trestle was placed, the beams and floor up to its head were laid; the second trestle was then established in like manner, and the work continued

in this way till completed. The trestles were about fifteen feet long, and placed sixteen feet asunder; five beams were used from trestle to trestle, and the floor formed of two rows of 1½-inch plank. Braces, strutting considerably, were driven down as far as possible into the bottom of the river, at each end of the trestles; and these were further strengthened by additional props placed vertically under the centres of the ridge-pieces; strong side-rails were then constructed, and the ends of all the trestles were moreover secured to cables stretched across on each side of the bridge.*

Expedients for Crossing Streams.

Carriages of burden, carts, or wagons are useful materials for making bridges across shallow rivers and canals. Figs. 1, 2, 3, 4, Pl. LXII., are plans and elevations of the *pont-roulant*, described in the French *"Aide-Mémoire."* Each pair of wheels, with their axle-tree, forms a sort of trestle, on which the beams and floor may be laid. The hinder axle-tree of a four-wheeled

* This description of the establishment of a broken communication by means of a trestle-bridge is given, not with a view, in any case, to recommend its imitation, but as a curious instance of the opinion which European military engineers have entertained of the difficulties connected with the construction of high trestle-bridges. It seems strange, that a trestle-bridge, only twenty-six feet in height and of inconsiderable length, should ever have presented difficulties, particularly when it was intended simply for an ordinary roadway. This fact is a remarkable contrast to the operations of the armies of the United States in Virginia. The Construction Corps of the Army of the Rappahannock built the bridge across the Potomac Creek, on the line of the Richmond, Fredericksburg, and Potomac railroad, of round sticks cut in the woods and put together without bolts, simply with spikes and pins. It was constructed of trestles in three tiers; its height was nearly 80 feet, and its length about 400 feet; the trestles of each series being about the height of the single trestle of the bridge at Dresden. This bridge was afterwards destroyed in the retreat of the army, and again reconstructed by the author; since which time it has carried daily the heaviest railroad trains. A full description of this structure is given in the section on Military Railroad Bridges. (See Frontispiece.)—AUTHOR.

carriage shifts upon the perch (Fig. 2), as in a common timber-carriage. The bearers O O (Figs. 1 and 2) rest upon the beds M M (Fig. 1) in travelling; but they may be shifted upon the uprights N N, at pleasure, according to the depth of water in which the bridge is to be laid.

In laying the bridge, the carriage is placed endwise on the bank of the river, and unloaded; the fore axle-tree is then lashed or bolted, to prevent the carriage from turning; the pole is taken off, the beams (P P, Figs. 2, 3) and centre flooring (Q Q, Fig. 4) laid, and the beams (R, Fig. 2) lashed to the hinder bearer O. The carriage is then pushed into the river, the balks S S laid to the further bank, and the floor completed. Two or more carriages may be used, according to the breadth of the river, if one is not sufficient. In this case, the carriage first put in must be dragged, by people previously sent across, toward the further side of the river, to make room for the other carriages that are to be placed in succession. It is highly necessary, therefore, to be provided with the means of sending one or two men, with the end of a small rope, across the river, by which to establish a communication. For this purpose, a small raft of timber, a float made of two casks lashed together (Fig. 8, Pl. LIX.) or inflated skins, may be used; or the carriage-bridge may be provided with a small boat or Welsh canoe (the boat of the ancient Britons), composed of a hide of leather stretched over a light round frame of basket-work, which is managed in the manner represented in Fig. 8, viz., putting the paddle into the water in front, and drawing the vessel forward; if the paddle were worked on either side, the float would turn upon its centre, without making direct progress.

It is not intended by this notice to recommend the adoption of the *pont-roulant* of the "*Aide-Mémoire;*" but there is no doubt that, used in this way, the ordinary wagons and carts of a country may be sometimes found very useful. A common timber-carriage, for instance, may easily be converted into a carriage-bridge, nearly similar to the French *pont-roulant*, by bolting beams (L and M M, Fig. 1, Pl. LXII.) in the axle-tree, to bear the balks clear of the wheels. If the bottom of the river in which a carriage-bridge is to be laid is soft, the broadest wheels that can be obtained should be used; if artillery is to cross, the wheels of the carriage-bridge should be taken off, a strong beam placed underneath each axle-tree (D, Fig. 1), and projecting to any convenient distance, E, on the right and left; then, the wheels being set on at that distance, the bridge will be made more steady. It will be necessary to take out the boxes of the wheels if the axles are of iron.

The chief difficulty in moving through a country much intersected with canals and wide ditches is to procure beams of sufficient length and strength to span such impediments. Columns of troops should, therefore, always be provided with planks or timber, of portable size, fitted so that, when put together, beams of the required length may thus be formed; and, as these materials must be transported on some sort of carriage, this also should be calculated to be of use in constructing a bridge.

A bridge for infantry may be made over a canal or river, not more than 50 feet wide and 11 deep, by the following application of two frames: Unload the carriage; place the back part towards the river, and

the shafts in the position B C (Fig. 1, Pl. LXIII.). Shift the beam A to such a position upwards on the shafts as the depth of the river may require. Set up and complete the frames; lay the end of one of them on the beam A, and lash it to the first transom (E, Fig. 5, Pl. LXII.). Confine the shafts in this position by the rope C D (Fig. 1, Pl. LXIII.), which fasten to the further end of the frame, and push the carriage into the water, till the end of the frame is within four feet of the bank (E, Fig. 2); then let go the rope C D, and push the frame outwards, until the shafts of the carriage are in a vertical position, which may be shown by a plummet (H, Fig. 2). The carriage is then secured in this position by guys from the points of the shafts, and from its under part, now at the bottom of the river, to the end of the frame P. The other frame, with the floor (H, Fig. 5, Pl. LX.) lashed to it, is then floated across, and one end hauled up to its place (L M, Fig. 2, Pl. LXIII.) by two men placed between the shafts; guys are then fastened to the end of the frame M, on the further side of the river, and the bridge is constructed. If one or two men are sent across previously, the operation would be facilitated, and might be executed in a very few minutes. This carriage-bridge bore, with perfect safety, as many men as could be put in march across it in single file; and, on the first trial, was laid in a few minutes, across a canal 9 feet deep and about 40 wide. Any strong two-wheeled carriage may be used in the same manner.

This carriage-bridge having been designed for a flat country, two wheels were considered sufficient; but four-wheeled carriages are preferable, and these would afford two sets of trestles or bearers.

Two ladders, resting at their lower extremities on the banks, as at E and G, and at their upper ends on an axle-tree between two wheels, or on the front of a cart, which has been driven into the middle of the stream, and turned till the shafts are in vertical positions, as at A C, form a convenient bridge, on which infantry may pass in single file, the rungs of the ladders being covered with planks.

The late Sir William Congreve's troughs (Figs. 6 and 7, Pl. LX.) are excellent expedients for crossing ditches, etc. They are 14 feet long, and 1 foot 6 inches broad. Three troughs are carried in one wagon. Laid alongside of each other, they form a bridge, for any nature of field artillery, across a ditch 12 feet wide; placed across boats, they form a communication at once, by this simple principle of combining the beams (A B, Fig. 7) with the floor (C, Fig. 6). St. Remi's carriage-bridge, floated by casks, is noticed.

A carriage-bridge for infantry, two abreast, was made across the Douro, between Tordesillas and Toro, with the spring wagons of the army. The bottom of the river was hard and even; the average depth, from 3 to 4 feet. The wagons were placed longitudinally, at distances suited to the lengths of the planks that had been collected for flooring, which were laid from wagon to wagon, the tail and front boards being taken out.

A bridge of like description was constructed by Colonel Delancy on another occasion; it was composed of common two-wheeled carts, by merely laying the ends of the shafts of each cart into the body of that in its front. The French likewise made use, several times, of the carriages of the country as bridges for infantry. But, with

the least increase of water in a river, such bridges are so much exposed to the danger of being carried away, that this experiment should never be made with any carriages essential to the equipment or progress of an army.

It is frequently necessary to resort to bridges of this description, to establish communications across rapid, but shallow rivers, in which boats or floating bridges of any kind cannot be used; or to bridge shallow muddy creeks or gullies, in which neither floating bridges, trestles, nor carriage-bridges can be applied. It will frequently be necessary likewise to resort to pile-driving to the low-water mark, at least, of tide rivers, to form wharves or abutments for bridges of boats or for flying bridges.

A bridge on piles was constructed across the Var, in 1708, a river which, in the autumn months, is subject to great floods. This bridge was carried away by one of those torrents, from not having applied *fender* piles and adopted other expedients which might have preserved it. In 1744 and 1792, bridges on piles for military communications were also constructed across the Var.

Piles are of great service to form breakwaters, to protect bridges in strong currents from the force of the stream, or from any thing floating in it, whether by accident or sent adrift to destroy the bridge. For this purpose, three or more piles, set in a triangular figure, should be driven above each raft, boat, trestle, or row of piles, and fastened together by strong cap-pieces of timber, well braced and planked, so as to form a powerful buttress or breakwater. When piles are to be driven for this purpose, the pile-engines must be set on boats or rafts, if the river be so deep that a scaffold on trestles cannot be applied.

Pile-driving for bridges will generally be undertaken for the more permanent communications of an army, and be executed at comparative leisure, with fit and proper means. The author, therefore, confines his observations, at present, to those temporary constructions which may be suddenly required in the movements of armies; suggesting, at the same time, a few expedients and substitutes that may be resorted to upon occasions in which the engineer cannot be furnished with regular means, and when but little time can be allowed for the execution of the work.

The first thing to be considered is a pile-engine, the rammer for which (a block of sound, heavy wood) it is generally more difficult to procure than it is to get beams 4 or 5 inches square, for making the frame; it may be observed, that an 8-inch shell, filled with melted lead, the weight of which is about 74½ lbs., would make an excellent ram.

The pile-engine may be 15 or 16 feet high; and, although the space through which the ram falls, when the pile is first set, be much less than this, yet, as the space increases in proportion as the pile enters, such a blow will at length be generated, that piles, set in rows of three or four, and driven till they will enter no further, will, with moderate intervals between the rows, bear any weight of troops that can be put in march upon a bridge constructed in this manner.

The ram or shell is discharged by a trigger (A, Fig. 1, Pl. LXIV.) from the top of the frame (Figs. 1, 2, and 3), by being pressed against the head (B C, Fig. 1), which withdraws the hook D from a ring-bolt which is fixed in the fuze-hole by the melted lead. The shell is confined

between the three standards (A B C, Fig. 4), and, as it falls, carries with it a triangular piece of wood (G G, Figs. 1, 2, and 3) fitted to their inner surfaces, and fastened by the ring-bolt to the shell, to keep it in the centre of the space comprehended between the standards A B C; so that, when the piece of wood (E F, Fig. 1) to which the trigger, hook, and rope are attached, is lowered upon the shell, the hook D may fall upon and catch the ring. The three standards (A B C, Fig. 4) are placed so that the point of contact of the shell with the beam A is at the middle of its inner face, but at the outward edges of the inner faces of B and C, and the three points of contact are equidistant. The side beams are thus placed, in order to receive between them a pile, E G, of sufficient scantling. With an 8-inch shell, the space will be sufficient to receive a pile (E F G H, Fig. 4), 6 inches by 7. An engine made with a 10 or 13 inch shell will thus receive and drive home piles capable of bearing any weight.

To make a scaffold on which to place the engine, prepare a frame (A D, Fig. 5) with planks E F, nailed obliquely near the point C, so that, when placed in the river, the flat surface E F may rest upon the bottom. Upon this inclined plane, lower the frame G K, till it rest upon the cross-piece X of the first frame. Then set G K upright, with beams attached, upon which, at Q P, a temporary floor may then be laid, for placing the pile-engine. Put weights upon these beams; and, if the frame should sink, withdraw it, and shift the pieces E F higher up, repeating the adjustment till the bearing is sufficient to support the pile-engine. Then secure the upright frame in its position with strong guys; place the

engine upon the platform, and drive a row of piles; when this is done, remove the pile-driver, lay the floor to the piles last driven, set out the temporary scaffolding as before, and proceed as above. If the river is too deep or muddy to admit of this expedient, or of laying a scaffold on trestles, pile-engines, placed on rafts or boats, should be used.

Figs. 1 and 2, Pl. LXV., show the method of driving piles in water practised in the Peninsula. The ram was worked by hand-ropes (Fig. 2) attached to the fall, which is a much quicker way than by the trigger and drop, and should, therefore, be generally used in such operations. The pile-engine (Fig. 2) was provided with a tackle, fastened at its head, by which to sling the pile and set it in its place. When boats cannot be procured, pile-engines may be constructed on rafts of timber.

When the bottom of a river is soft, and no hard substratum near, piles of considerable length will be required. These it may be difficult to obtain, and not easy to drive with ordinary pile-engines, on account of the small space left for the ram to fall through, when the pile is first set. Under such circumstances, a small frame or shoe, A B (Fig. 6, Pl. LXIV.), should be fixed at a proper distance from the point of the pile, to allow it to enter sufficiently into the soil to insure a firm holding; when, by means of the frame A B (which may be made large or small, according to the nature of the soil, and weight to be borne), the bearing will be increased, and the weight made to act on a larger surface. For temporary bridges, this expedient will be found to answer, though not for permanent purposes, because the action of the

current will, in time, undermine the piles, and permit them to sink.

In driving piles for temporary supports, in soil which would require long piles, consequently much time to drive them *home*, and would involve the difficulty of procuring timber of sufficient length and scantling, the principle of the preceding expedient may be more generally applied, by constructing, on shore, frames which may be afterwards placed vertically, in the proper situations, after the bottom of the river has been levelled to receive them. These upright frames are fitted at bottom in gratings of timber, the planes of which are perpendicular to the others; so that, when sunk in the river, each vertical frame stands perpendicularly upon a strong horizontal basis, formed of an open frame; through the square interstices of this, short piles are then driven, to keep the horizontal gratings and vertical frames secure. The upright frames should have their sides and ends planked; and, when placed, the interior space thus formed, should be filled with gravel or small stones, and the ends of the frame which are opposed to the current worked off to sharp edges; if necessary, these should be covered with sheets or coats of iron, as a security against ice or other floating matter.

The following ingenious method of sinking piles in rivers having soft beds is practised in Ceylon. The piles are carried in, and set upright in the intended position, either by hand, or from boats or rafts, with fan guys fastened to the head of the pile. Two or three men then climb up to the head, and hold on by the guys. The piles are then caused to wabble, by swaying upon the guys, by which the holes are progressively enlarged,

and the piles, sinking in proportion, soon become sufficiently bedded to be braced together; they are capable of supporting very considerable weights, if the superstructure be properly constructed.

Fig. 1, Pl. LIX., is a very simple method of driving piles by hand, and of combining pressure with the operation. The pile is set, and kept in its place by means of two spars or planks, as represented in the figure; their ends resting upon, and attached to a stool fixed on the bank. A plank is then laid across, upon which one or two men may stand to drive the pile by hand-mauls, or work conjointly, a heavy two-handed beetle; the weight of the men, which may be increased by laying stones on the platform, assisting to force the pile into the ground; when one row of piles is placed, and the floor laid to a cap-beam fixed upon them, another row may be set and driven in the same manner, fixing the stool on that part of the floor which will thus have been completed. Piles, driven in this way till they enter no further, may safely be depended on to bear infantry on a front of two or three files, with open ranks, and not keeping step—a precaution, which it is always of great importance to observe in crossing slight bridges.

Trussed Bridges.

In restoring, by carpentry, communications across broken arches, and (as in following up a retreating army) when only one side of the impediment can be got at, the great difficulty is to get the first beam across the gap. The method of effecting this, shown in Fig. 3, Pl. LXV., was frequently resorted to in the Peninsula. For this a pair of wheels and an axle-tree are sufficient; and the

process is so incapable of injuring them, that gun or wagon wheels, or limbers, may with great propriety be used, taking care, if a limber, with its shafts (the ammunition boxes being removed) is employed, to lash two beams (one of which, A B, only appears in the figure) to the shafts, so as to project beyond the wheels. Then, the beam C, to be laid over, being placed on skids sufficiently high, the carriage, with the beams A fixed as described, is backed till the axle-tree is a little within one end of the beam C; the beams A are then elevated, at the ends where the men are in the figure, till their opposite points are so much depressed as to admit of the cross-beam B being placed underneath the beam C, which is to be laid across the impediment. The lever A is then worked downwards, and as soon as the beam is lifted, the whole is easily moved forward to the edge of the gap, where a high sill should be laid, to prevent the wheels from approaching too near.

The following ingenious method, practised at the Royal Repository, may be used, if the chasm or river is not too deep, or the bottom not very soft. Take two beams (1.1, Fig. 3) and fasten them together, crossed near the ends, to form a fork. The beam to be laid across is then placed in the fork, as shown by the dotted lines in the figure, and lashed to it. The whole is then pushed from the near side, and, if there are persons to aid on the further side, pulled across; by which means the beam intended to be laid is got athwart in a very easy and simple manner. A communication being thus established, there will be little difficulty in laying the remaining beams, and in completing the bridge.

The following method of repairing a breach in a stone

bridge 100 feet wide, with timber not much above half that length, without support in the bottom of the river, was practised by the staff corps in crossing the Agueda. Three spars, A B C, Fig. 2, and E F, Fig. 1, Pl. LXVI., were placed at a sufficient distance from the gap on each side, and framed together. Two rollers of unequal diameter (1.2, Fig. 1) were then placed under each frame, and the platforms D D, loaded with stones and sand-bags, until the points F F of the beams were raised to a sufficient height; the frames were then moved forward until the beams overlapped at H. The points of the beams were then lashed together, as at A B C, Fig. 2, and a good communication was thus formed.

The stone bridge across the Coa at Almeida, having been destroyed by the French, in their retreat, and a passage across the river there being necessary for the operations of the allied army, a communication was established in the following manner: Notches, A B (Fig. 3, Pl. LXVI.), were made in the masonry, and two frames, A F, B E, eased down, vertically, from the edges of the gap, in the upright positions A F, B E, resting upon the notches A B. Two tackles, applied to each frame, led to ring-bolts set in the masonry at about 30 feet from the gap. Fifty men being put to each tackle, the frames were lowered down to cross each other at H. Gang-boards were then shoved out, and men sent to put in key-bolts, previously prepared; a ridge-piece was then fixed in the fork H, the beams laid, braces 1, 2, 3 put in, and the communication served without shake or failure.

The bridge, Fig. 1, Pl. LXVII., was constructed across the Coa, in the neighborhood of Puente de Pinkel, at a

time when it became extremely important to establish good communications across that river.

It was found impracticable to restore a communication across the stone bridge, on account of the shattered state of the piers, and the difficulty of procuring good and sufficient timber to span the broken arch. Six poplars, and some elms that grew on the river bank about two miles further up, were all that could be procured. These were immediately felled, launched into the river, and, with great difficulty, floated down the rocky stream. With such limited means, it became necessary to select the narrowest parts of the river for the sites of the intended bridges; but, agreeably to a principle in hydrodynamics, the velocity of the current in different sections is reciprocally as those sections; therefore, at the parts chosen, the stream was so rapid, that no hold could be got of the bottom of the river. The width was 60 to 70 feet. The two bridges were precisely similar to each other, and one only, therefore, need be described. It was found impracticable to get any person across the river to facilitate the laying of the first beams; but this great difficulty, arising from the want of aid on the opposite bank, was got over in the following ingenious manner: The profile of the bank upon which the bridge was to be prepared, was, as shown by the dotted line in Fig. 1, Pl. LXVII., extending from B to A, of solid granite. The profile of the cliff there was reduced to B D A, by cutting away the rock to about 8 feet, and notches, D, worked into the rock, to receive the ends of the beams. The mass of the masonry, B D, was then laid, and capped on the extreme edge by the beam C; whilst this work was being executed, a road was made along

the face of the rock from A to B, Fig. 2. Two trees (C K, Fig. 2) were then placed, with their large ends inserted in the notches D D, Figs. 1 and 2, and, by the help of levers and crowbars, the trees were made to turn upon the ends lodged in the notches D, until brought into the positions F D, E D. Handspikes were then lashed across the trees at convenient distances, to enable some men to crawl out to the ends of the trees; two light poles H I, Fig. 1, were then pushed across to the opposite bank, and upon these two or three men slid over. A communication being thus established, the work was soon completed.

Methods of constructing temporary bridges of rough timber, or trees, without using nails, or employing fine workmanship, will always be found of signal use on service; and officers of all arms, and all ranks, would do well to study resources of this kind. Light troops, in particular, should be acquainted with expedients so necessary to facilitate the operations of the army with which they may be acting, or to favor their own desultory enterprises, in a country where timber is abundant.

If, for instance, a body of infantry, either acting singly, or forming the advanced guard of an army, should be brought to check by a narrow, unfordable river, where boats cannot be obtained; and, if trees, long enough to span it, are growing on the banks, a communication may easily be made, by felling a tree into the water, confining the trunk to the bank, and letting the current force the head round to the opposite side, against which the branches will be jammed with such force, that the tree will bear weight by its strength, as well as by its buoyancy.

If the river be too wide to be spanned by one tree, and that two or three men can, in any manner, get across, let a large tree be felled into the water on each side, and placed close to the banks, opposite to each other, with their heads upwards. Fasten a rope to the head of each tree, confine the trunks, shove the heads off to receive the action of the current, and ease off the ropes, so that the branches may meet in the middle of the river, Fig. 5, Pl. LXVIII., in an angle pointing upwards; the branches of the trees will be jammed together by the force of the current, and so be sufficiently united to form a tolerable communication, when a few of the upper branches are cleared away. If insufficient, towards the middle of the river, to bear the weight of men crossing, a few stakes (C D, Fig. 7.), with forks left near their heads, may be thrust down, through the branches, to the bottom of the river, and hitched to the main branches of the trees; or the force of the current may be made to yield vertical support to the communication, by applying a few planks, forming a plane A B, Fig. 7, inclined to the surface of the current in an angle of about 50°; by this means, that power which, in the flying bridge, acts horizontally, may be obtained vertically, in a manner that will greatly add to the stability of the rough structure.

If no communication can be established with the further bank, fell two large trees, and one of middling size, and place them in the water. Take one of the former—place it as represented by A B, in Fig. 6, Pl. LXVIII., and confine it in position by a rope to the bank *c*; press the heel A of the first tree down in the water, by placing two or three men on it, in order to

raise the head as much as possible during the following operation: Lash one end, D, of the small tree D E, upon the tree A B, at about one-quarter of its length from the top, the end E abutting on the bank; float the remaining tree downwards, and place its heel upon the second tree, at a few feet from its junction with the first, by keeping down the end E in the water; then shove off the third tree, till the current catches it on the near side; whence it will be forced round, and jammed with so much force under and amongst the branches of the first tree, as to form a practicable communication; this may afterwards be supported from the bottom by the current, by the means recommended in the preceding cases.

Simple Trusses.

Figs. 4, 5, and 6, Pl. LXVI., are bridges formed of four or six rough trees, secured at their crossings by the cross-pieces (slots in carpentry) A B, Fig. 4, and A B C D, Figs. 5 and 6, which are so explanatory of the principle, that a description is unnecessary. To support the beams till their ends are crossed, and the slots put in, or to move the bridge, ready made, to its place, a pair of carriage wheels and an axle may be of great service, either by lodging the end of the bridge upon the axle, and so drawing it over entire, Fig. 4, Pl. LXVII., or by lowering the frames to their bearings upon the slots, in the manner represented by Fig. 3. Thus, suppose one end of a frame (A B, Fig. 3) fastened to an axle (which should be lengthened, if possible, to give the bridge a wider base), and C D, another frame, bolted or pinned to the first in E, and movable about it. Get up the two frames upon the edge of the river, Fig. 3; haul or push

the wheels towards the other side, till the frames come down to their proper bearings upon the slots, and the bridge is laid. The frames may be supported in the middle by a prop F (Fig. 4), on each side, standing perpendicularly upon a surface of boards, or set in the axle-hole of a wheel having a few boards nailed or lashed to the faces of the spokes, so that, in either case, the supports stand upon a large surface of soil.

Fig. 8, Pl. LXVIII., and Fig. 5, Pl. LXVII., are representations of a very ingenious bridge, composed of a few beams and a pair of wheels, invented by the late Lieutenant-General Sir William Congreve, of the Royal British Artillery. It is very light, and, consequently, may be constructed at a distance from the river, or ditch, which it is intended to pass, and rapidly run up, by hand, for instant application. The ends of two beams, A B C D, Fig. 8, are fastened to the axle-tree, and the other ends attached to the beams A D; the opening A G D is regulated according to the known breadth and depth of the impediment, and the beams supported in the middle by a post G H; the floor is formed of a few light planks. This bridge may be thrown across a small river, or a considerable ditch, in a very few minutes, without previous indication of the part to be attempted, and may be quickly formed of cart or any other carriage wheels, and a few light spars.

The purpose for which the late Sir William Congreve designed this expedient was to accompany columns of attack in the assaults of field-works. The beam A B, Fig. 2, Pl. LXVIII., is supported, during the advance, by ropes; the beams C D are attached to A B in C, and the other ends D rest upon A E. To cross a wet ditch

the machine is run up and pushed into the ditch until E, the end of the beam A E, rests on the edge of the counterscarp; the beam A B is then let fall, when a bridge will be formed as represented in the figure.

This machine may also be found useful in passing deep dry ditches, by facilitating the descent, forming a passage over palisades, chevaux-de-frise, etc., or serving as a scaling-ladder to ascend a rampart; or, by means of carriage-bridges upon this principle, deep narrow ditches may be crossed without descending into them, if the beams A B, Figs. 3 and 4, Pl. LXVIII., be made long enough to reach to the crest of the exterior slope or escarp before the wheels quit the edge of the counterscarp. As the ditches of field-works are commonly defended by caponnieres and reverse fire from casemated counterscarps, to make up for the want or deficiency of flank fire from the parapet, so any expedient by which a ditch thus protected can be crossed at the top is deserving of favorable consideration and adoption. But these expedients can only be resorted to when the ground in front of the work is clear from local impediments or artificial obstacles, so that several carriage-bridges may be run up in line. If the ground be soft, such machines would occasion but little noise in their movement; and, by nailing leather on the wheels, using leather washers, and other precautions, noise might be almost entirely prevented. Expedients of this nature may, undoubtedly, be of service, either in the assault of works, or to cross any ditches, canals, or other impediments by which the approaches to the works may be covered; and, although attempts by such means may be difficult, yet the losses attending them will not, in general, be so great

as in filling up ditches, inundations, etc., by materials carried up by hand under a heavy and protracted fire. * * * * *

Suspension-Bridges.

From the equations to the catenary, the weight of the whole bridge, the span, and the sagitta or droop of the cable or chain being given, we derive the following practical rules:

1. The whole length of the rope or chain is found by dividing eight times the square of the droop (C V, Fig. 9, Pl. LIX.) by three times the span A B, and adding this quotient to the span itself.

2. The weight of one foot of the bridge is found by dividing the whole weight of the bridge by the whole length of the rope or chain.

3. To find the *tension* or *strain* at the lowest point, add three times the square of half the span to the square of the droop, and divide by six times the droop; this *length*, in feet, multiplied by the weight of one foot, obtained from Rule 2, will give the strain required.

4. The tension or strain at the highest point in the direction of the chain or curve is found by adding the droop to the length obtained from the preceding rule, and multiplying this sum by the weight of one foot.

5. To find the angle which the curve makes with the vertical A or B, the point of support, divide the weight of half the bridge by the tension found in Rule 4; the quotient will be the cosine of the angle which a tangent to the curve at A or B makes with a vertical line.

If the continuation of the rope or chain over the point of support be equally inclined to the vertical line passing through that point—which is very desirable, in order that the direction of the resultant or the combined effort of the two forces may be vertical—and consequently fall *within* the pier, we shall have these additional rules:

6. The pressure upon *each* pier is equal to the weight of the bridge between two piers.

7. The tension or strain at the point where the chain is fixed to the ground is equal to the tension at the highest point (Rule 4).

As it appears from Rules 1 and 3 that the length of the curve is but little affected by the magnitude of the droop, whereas the strain at the lowest point varies *inversely* as this droop, very nearly; and, consequently, the greater the droop the less the strain in the same proportion; so it is evident that the droop, or versed sine, should be made as great as other circumstances will permit.

In suspension-bridges, the weight of any portion of the roadway is proportional to the corresponding horizontal ordinate of the curve, and not to the corresponding arc; yet, in the cases which we have to consider, the curve is so flat that the error on that account is unimportant, and the curve assumed by the chain may be considered as the ordinary catenary.

The rope bridge (Figs. 10 and 11, Pl. LIX.), described in the French Aide-Mémoire, is thus constructed: A A are trestles placed on each side of the river, level with the roadway, for the abutments of the bridge. The ridge-beams of the trestles are 1 foot square and 16 feet long, with grooves in the upper surfaces to receive the six cables, K K, laid 19 inches apart.

Beams B B, 20 feet long and 6 inches square, are laid from the banks of the river to the trestles, to relieve the floor-cables of that portion of load. I I are two supension-cables, 5 or 6 inches in circumference, leading across the river, at 10 feet apart, and passing over the heads of strong trestles or gins, E E, 14 or 16 feet high, placed on each bank of the river. The suspension-cables, with a tackle L attached to each, are adjusted, by capstans placed in the rear, to the proper degree of curve or drop. C C are traverses, 11 feet long and 4 inches square, with rings at each end, placed under the cables K K, at intervals of ten feet, and suspended to the cables I I by the tackles F F. D D are planks, 1 foot wide, 11 feet long, and 2 inches thick, for flooring.

The tackles F F are fastened, at every 10 feet, to the suspension-cables before they are passed across the river, so that every traverse, C, when placed underneath the floor-cables, finds, over-head, its particular tackle, F, which, being hooked to the rings of the traverse, and hauled upon, connects the floor-ropes with the suspension-cables, I I, and thus forms the compound catenary, 1, 2, 3, in its position of equilibrium with the floor-cables, which, though stretched nearly in right lines, form likewise a curve of the same nature. H is one of several piles or frames of timber sunk in the ground, to which the capstans and floor-cables are secured.

The cables for the floor of the bridge are 3 inches in diameter, and stretched across the river by capstans placed alternately, so that the fixed point of one cable adjoins to the capstan which stretches the next. It would be dangerous to have all the capstans on one side, and, consequently, the cables stretched in one direction only.

From this description, the method of laying the bridge is very obvious. First, place the trestles for the abutments at the proper level; and, if no trees or other strong fixed points are near, sink frames and piles deep into the ground, to secure the cables and capstans required for constructing the bridge.

Fasten the vertical tackles to the suspension-cables, commencing at 13 fathoms from the parts which are to rest on the head of the suspension-trestle, and fasten the end of each tackle to its lower block, so that it may easily be reached from the floor.

Establish on each bank of the river a strong trestle, or two gins, 10 feet apart, and pass the suspension-cables over the ridge-pole to the blocks L L, and adjust the cables by the tackles and capstans, until the lower point of the curve be a little above the horizontal line between the two floor trestles. Stretch the six floor-cables across, and fasten them alternately to a pile or other fixed point on one side of the river, and a capstan on the other. Place three men, numbered 1, 2, and 3, on the trestle A on each side, 1 and 3 being provided with pole-hooks sufficiently long to reach the first pair of hanging tackles, F. Let three men, numbered 4, 5, and 6, follow, 4 and 6 carrying a traverse. Then 1 and 3 will catch the hanging ends of the first tackles, give the falls to number 2, the hooks to number 5, and, receiving a traverse from 4 and 6, pass it under the floor-cables, and hook it to the tackles F F. Numbers 1 and 3 then haul out the traverse to its place, with two or three planks lashed to it, proceeding in this way from C to C until the bridge is completed. When all the tackles and traverses are in place, but slack, the whole should be nicely ad-

justed to retain the suspension-cables in their position of equilibrium. The temporary floor is then removed, the planks laid across the floor-cables, and lashed to those on the outside.

The weight of cordage and appurtenances of a rope bridge of this description, for a river about 130 feet wide, is about 12,490 pounds. When infantry are marching over, under a front of three men, with ranks three feet distant from each other, the bridge will have to sustain about 120 men. Their weight, each taken at 180 pounds, is about 21,600 pounds, which, added to 12,490 pounds, gives 34,090 pounds, the weight to be borne by six 3-inch cables forming the floor of the bridge, and the two 6-inch cables to which it is suspended—a weight which they are well able to sustain.

In this construction, as indeed in every case in which the suspension principle is applied, care should be taken, in adjusting the vertical tackles or rods, that the floor may have a small degree of convexity upwards, in order to allow for the sinking of the roadway which unavoidably takes place, after a time, in consequence of the elongation of the upper cables or chains from which the road is suspended.

In applying the rules stated on page 281 to the bridge just described, where the span=130 feet, the droop=12 feet, the weight of the bridge unloaded=12,490 lbs., and when loaded with infantry=34,090 lbs., we obtain the following results:

1. The whole length of the curve . . . 132.95 ft.
2. The weight of 1 foot of the length of the br[illegible] when unloaded . . . 93.94 lbs.
   Ditto, [illegible]ded . . . . 256.41 "

3. The strain at the lowest point, when unloaded	16,726 lbs.
Ditto, when loaded	45,652 "
4. The greatest strain or strains at the highest point, when unloaded . .	17,853 "
Ditto, when loaded	48,729 "
5. The angle which the chain makes with the vertical at the highest point .	69° 32′
Now, it appears, that a rope 1 inch in circumference is capable of resisting a strain of 2¾ cwt., and, therefore, a rope 3 inches in diameter, or 9.42 in circumference, will withstand a weight of .	27,350 lbs.
And a rope 6 inches in circumference . .	11,088 "
Hence, the six floor-cables will withstand	164,100 "
And the two suspension-cables	22,176 "

The bridge, Figs. 10, 11, Pl. LIX., derives the greater part of its strength from the floor-cables K K (Fig. 10); and it is evident, from what has been just stated, that these, even without the others, are capable of resisting the strain to which they may become subject, from the passage of troops of any arm over the bridge, as in Fig. 4, Pl. LXIII. The floor-cables, though stretched nearly into a right line, are urged more or less into the catenarian curvature, by the weight of the cables and floor; and the strains upon them may, therefore, be readily determined by the formulæ for the tensions.

The manner in which rope-work was applied for the passage of the Tagus in 1812, by the late Lieutenant-Colonel Sturgeon, of the Staff Corps, and other intelligent and distinguished men, together with the use afterwards made of cables in the passage of the Adour, are instruc-

tive examples of the convenience and efficacy of such expedients.

One of the principal arches of Trajan's bridge across the Tagus, at Alcantara, having been destroyed by the French, Lord Wellington found it necessary to direct that a communication over that bridge should be re-established, for the purpose of bringing up artillery and stores from Badajos, for the attack of the forts at Salamanca. Timber of sufficient dimensions to effect this could not easily be procured; and, indeed, any application of that material to make good such a fracture would have been extremely difficult, and required much labor to be performed on the spot, in fashioning, framing, and setting up the work; and which, consequently, would have given warning to the enemy, before the campaign opened, of some important movement in that quarter being intended.

To obviate these difficulties and objections, the officer sent, in April, 1812, to make preparations for this operation*—a man of fertile genius and great practical knowledge—happily devised an application of cordage, which might be prepared secretly, and even in privacy, at any distance from the place at which it was to be used; it might also be easily transported thither entire, and speedily stretched across whenever it might be required. The formidable impediment was very nearly 100 feet wide. The materials of which this extraordinary work was constructed were as follows:

1. 4 beams of poplar, each 30 feet long, 12 by 8 inches.
2. 8 ditto, each 20 feet long, 6 inches square.

* The late Lieutenant-Colonel Sturgeon, of the Royal Staff Corps.

3. 48 joists, each 12 feet long, 3 by 5 inches.
4. 120 ditto, each 12 feet long, 1½ by 5 inches.
5. 100 half-inch screw-bolts, each 10 inches long.
6. 100 inch and half planks, each 12 feet long, 1 wide.
7. 50 two-inch planks for the ends, same dimensions.
8. 10 triple blocks, sheaves 12 inches diameter; brass cogged and iron pinned.
9. 10 double, ditto, ditto.
10. 10 double blocks, sheaves 6 inches diameter, for working tackles and guys.
11. 10 single, ditto, ditto.
12. 450 fathoms 6½ rope, for great net and bridge bearers.
13. 200 ditto 4½ rope for falls, for bridge tackles.
14. 200 ditto 2½ rope, for working tackles and guys.
15. 100 ditto 4½ rope, for straps round the beams.
16. 1000 ditto 3 and 4 yarn; spunyarn.
17. 140 yards strong tarred canvas.
18. 500 weight bars of iron, for cramps and bolts.
19. 200 lbs. of lead.

Tar, rosin, grease, marling-spikes, files, old canvas for parcelling, salvages, straps, tail tackles, twine-needles, a portable forge; blacksmith's, mason's, and carpenter's tools; drill-hammers, scrapers, and needles.

Two pontoon carriages.

Four crabs or small capstans.

The rope-work was put together in the pontoon-house at Elvas, in the following manner: two beams (1 in the preceding list) B B, Figs. 4 and 5, Pl. LXIII., laid in trestles 4 feet high, placed 90 feet asunder, were first secured to the end walls of the house by tackles and braces. The 6½-inch cable (12) was then stretched out

in eighteen lengths, or rows, round the beams B B, with a uniform, moderate strain, such as to admit of the parts or rows of the cable being drawn together by strong lashings, at alternate points, and formed into a body of network (Fig. 6); the two outside rows of the cable being first steadied by tackles to the side walls of the house, to resist the inward strains resulting from the process, and to retain the net-work of uniform width throughout.

Cross-beams (2), C C, Fig. 5, and profile under Fig. 4, having channels cut in them, and seared to smoothness with a heated iron (the arm of an axle-tree), were then laid on the network, each notch receiving its corresponding portion of rope, and firmly lashed by spun-yarn (16) at all the crossings.

The beams D, Fig. 5, were prepared in a novel and ingenious manner, with the materials (3) and (4) mentioned in the preceding list. At each end of a beam (3), two of those of the narrower dimensions (4) were connected with it by screw-bolts (5), and in this manner the jointed beams D, Fig. 6, formed alternately of single and double pieces, were easily set up, and prolonged to the full length of the floor of the intended communication, when required for use.

Several important objects were accomplished by this ingenious contrivance. The individual parts were of very convenient length for being transported on carriages, easily put together, and readily adjusted as the work proceeded. The beam of the larger dimensions in breadth (3) was used for the single part, whilst two of half that dimension (4) were applied to form the link which connected it with the next single beam, and these gave to

the whole a sufficient and nearly uniform strength. The joints resting upon the cross-pieces C C, permitted the beams D D to conform, by their flexibility, at the points C C, polygonally,* with the curvature of the bridge; and the bearing of the double portions of the beams on each cross-piece C, being nearly 8 inches, was more favorable to the solidity of the whole than could have been effected in any other manner. The beams D, thus formed and laid athwart the cross-pieces C C, had their joints adjusted to lie exactly on those bearers, and were then firmly lashed at each end of the bridge.

Planks (6) and (7), for flooring E, Fig. 5, were provided, with holes bored in the end of each, to admit of their being lashed to the beams D, and to each other.

This vast net, when completed, with its end beams B B, and traverses C C, was rolled up, firmly bound together, and loaded on a pontoon carriage. The means of transport for the whole apparatus were two pontoon carriages, each drawn by four oxen; and the lighter materials in seventeen cars, drawn by two oxen each.

At a sufficient time previous to the removal of the materials for application, an intelligent officer, Lieutenant Perry, was sent to superintend the cutting of channels

* The bearers of the roadway of the bridge being placed at the nine angular points, the bridge may be considered as a species of funicular polygon, and the various strains at the different points may be found by the composition and resolution of forces. It is evident, however, that we cannot far err in supposing the line of the bridge to be the ordinary catenary and in calculating the strains on this supposition.

The weight of the bridge, unloaded, may, perhaps, from the materials given above, be estimated at 18,000 lbs.; and when covered with infantry, three men in front, the load may be taken at 18,000 lbs. more. We shall therefore have, from the Rules on page 281:

The whole length of the cord or bridge$=100.24$ feet.

The weight of 1 foot of the bridge$=359$ lbs.

The strain at the lowest point$=416 \times 359=149{,}344$ lbs., which is to be supported by the strong rope network.

in the masonry of the bridge, to receive the straining beams R, to which the tackles G (13) were to be fixed.

To facilitate the laying of the bridge, two strong hawsers (6), represented by the lines drawn longitudinally under the floor of the bridge, Fig. 6, were stretched across the gap as conductors, upon which the further end of the network might be hauled over.

A tarpaulin (17) F F, Fig. 5, 4 feet wide, was stretched along the outside ropes, as a blind for cattle and horses; and tackles H H, fixed to two of the cross-beams C C, and to ring-bolts set in the masonry below, to brace and steady the bridge. A railing, formed of posts and ropes, completed this extraordinary work, and the whole was finished in time to open a passage across the Tagus for the column of siege artillery, under Colonel Sir Alexander Dickson, who crossed it on the 11th, and arrived at Salamanca on the 20th of June.

Santa Cruz, in his '*Réflexions Militaires*,' mentions a method of getting artillery over rivers, by slinging the carriages (Fig. 2, Pl. LXIX.) to blocks running upon cables, stretched across from bank to bank. This expedient may be useful: the horses may be swum over, and the carriages, ammunition, etc., crossed in the foregoing manner, when there are no means at hand to make a better communication. If the horses be crossed first, they may be yoked to ropes attached to the blocks, and thus haul the carriages over; the blocks may then be drawn back by the men left on the near bank.

If means sufficient only to transport the ammunition and men can be obtained, and the horses can be swum over, the gun-carriages and wagons may be dragged through the bottom of a river by their horses, if yoked

by strong ropes to the carriages. If there is not clear space on the further bank sufficient for the horses to work upon with facility, capstans, provided for the purpose, may be used; or a very good substitute for a capstan may be formed of a carriage-wheel (Fig. 2, Pl. LX.) laid upon its face on the ground, with an axle put into it, fitted with a round piece of timber as the barrel of a capstan, and bars to work it lashed across the head.

Whenever this method of getting artillery across a river is attempted, the passage should be undertaken at a straight part (to avoid soft banks), where the stream is most unbroken and the surface smooth—indications of a corresponding regularity in the bed which may be safely relied upon.

If the banks are steep, ramps should be cut at the places fixed upon for the descent and ascent of the carriages. If the river be wide, and the bottom soft, the guns and wagons should be unlimbered and crossed singly. In a soft bed, the penetration of the wheels in crossing may be partly prevented by attaching casks, air-cases, inflated bags, or other buoyant bodies to the carriages; by these means they will lose as much of their weight in water as is equal to the power of buoyancy attached to them, or to the weight of water displaced by the carriages themselves.

The power of using these expedients should not interfere with exertions to prepare better communications; the author mentions them to show what may be done, and to explain, generally, to staff officers, resources which it is of the first importance they should be acquainted with, for planning and executing bold enterprises out of the common line; and it should be remarked that the various

expedients for getting artillery across rivers should be particularly cultivated; for, by such means (as cavalry and other horses may be swum over, as well as those of the artillery), troops of all arms may, upon emergencies, thus get across rivers with means sufficient only for constructing slight bridges for infantry.

M. Vaillant gives the following description of a rope-bridge constructed for experiment near Punhete, in Portugal, in 1810, by M. Robert, Capitaine des Ouvriers de l'Artillerie. The floor was formed of six cables stretched by means of gins, laid horizontally, and fastened to beams laid across the trunks of two trees, which were found conveniently placed on one side of the ravine; and, on the other side, fastened by good tackles to a beam sunk horizontally in the ground, behind strong piles. This bridge was found sufficient for infantry. For artillery, the bridge was strengthened in the following manner: On each bank of the ravine, a potence (formed of two upright posts and a beam laid across their heads—a gallows), 15 feet high, was established, and supported by stays or shrouds attached to strong pickets or piles set in the rear. Two suspension-cables were passed over the heads of these potences and fastened at one end to a fixed point, and at the other to a capstan. Eight vertical tackles were fastened to the suspension-cables to connect the floor-cables with them, in the manner shown by Figs. 10, 11, Pl. LIX.

Strengthened in this way, the bridge bore an 8-pounder and limber drawn by four horses, the total weight of which was about 6,600 lbs., which, added to 2,009 lbs., the weight of the whole, gives about 8,609 lbs. for the total weight which the cables bore.

This bridge was used experimentally to instruct the pontoniers, but never applied in the operations of the army.

In 1820, a bridge on this principle was thrown across the Scarpe, near Douay, by Captain Robert, and a committee of artillery officers reported favorably of the construction. The apparatus, sufficient for a river 120 feet wide, was easily transported on two carriages, the total weight being about 6,697 lbs.

The floor was formed of 6 cables, fastened to, and stretched by means of frames, laid horizontally on each side of the river, behind piles sunk as deep as possible in the ground. A vertical frame, forming a potence or gallows, was fixed upon each of the horizontal frames, with two iron rollers on the summits, over which the two suspension-cables were passed and adjusted to proper tension by capstans. Tackles were fastened to the suspension-cables, at 6 feet distance, to combine, as before, the suspension-cables with the floor-cables. This bridge bore an 8-pounder limbered up and ten men.

The ropes which supported the floor appear, in this case, to have been braced together diagonally by two strong ropes, crossed several times in the form of a lozenge from side to side, by which the movement of oscillation, which is one of the greatest objections to this nature of bridge, was very much diminished. The potences for the suspension principle were about 15 or 18 feet high, strongly stayed by ropes to fixed points in the rear, and the floor-cables so braced to form an angle upwards, in the manner represented in Fig. 1, Pl. LXIX.

These experiments are said to have been very satisfactory. The bridge was subjected to several severe

trials. It was first erected on the ground in a length of 34 yards. Infantry, cavalry, and artillery passed without difficulty. Twelve-pounders, drawn by six horses, and 4-pounders, each drawn by four horses, crossed in repeated and continual succession, to try the effect of continued strain. Three of the guns were continually on the bridge at the same time. Infantry passed by double files, and then by sections of six files; first, at the ordinary pace, then in double-quick time; and occasionally halted in mass. Cavalry passed several times in double files, and once by fours. The bridge resisted perfectly; the floor did not even sink to the horizontal line with the lesser of these loads; it only sunk to that level under the weight of infantry halted in mass, and of cavalry passing by fours.

The bridge was then laid across a branch of the Oise, 30 yards wide. Infantry first passed four times across the bridge, two abreast, in double-quick time, ranks close, then by sections of five files, each time followed by an 8-pounder drawn by four horses. The oscillation, imperceptible with the gun, was but little sensible with the infantry, and not a man fell during these experiments.

The bridge was afterwards laid on land for further trial, when a 24-pounder, drawn by forty men, was taken across. This experiment completely succeeded, although one of the cables broke.

With these details, it must be remarked that it requires triple the time, at least, to make such a communication as to establish a bridge of boats or of trestles. When such means as these cannot be procured, or when, on account of the difficulty of transport or the rapidity

of rivers, neither trestles nor floating bridges can be applied, suspension-bridges are highly valuable resources to the military engineer.

The following is an account of a rope-bridge, extracted from Stevenson's "Twenty Years' Residence in South America." The ropes were made of the fibres of the leaves of the maguey. The leaves are first bruised between two stones, and left to soak in water until the vegetable part can be easily separated from the fibres. They are afterwards taken out and beaten with a stick, then washed and dried, and twisted by hand into cords. The bridge is stated to have been 38 yards long; the principal ropes, five in number, were fastened to a large beam sunk horizontally in the ground; and, on the other side of the river, fixed to a beam placed behind two rocks. The floor was 4 feet wide, and a network placed on each side for safety. The bridge having a considerable bend or droop, the swinging motion was very considerable, and the bridge appeared to be dangerous; but Mr. Stevenson states that he has often seen droves of mules and horned cattle cross in perfect safety. These bridges, which are common in South America, are called "Puentes de Maroma" or "Amaca," and by the Indians Cimpacha, a bridge of rope, or Huascachaca from huasca, a suspended cord.

We find the following account of a suspension-bridge in General Miller's Memoirs, Vol. I., p. 172:

The Maypo is a torrent which rushes from a gorge of the Andes. The only bridge over it is made of what may be called hide-cables. It is about 250 feet long, and just wide enough to admit a carriage. It is upon the principle of suspension, and constructed where the

banks of the river are so bold as to furnish natural piers. The figure of the bridge is nearly that of an inverted arch. Formed of elastic materials, it rocks a good deal when passengers go over it. The infantry, however, passed, upon the present occasion, without the smallest difficulty; the cavalry also passed without any accident, by going a few at a time, and each man leading his horse. When the artillery came up, doubts were entertained of the possibility of getting it over. The general had placed himself on an eminence to see his army file to the opposite side of the river. A consultation was held upon the practicability of passing the guns. Captain Miller volunteered to conduct the first gun. The limber was taken off, and drag-ropes were fastened to the washers to prevent the gun from descending too rapidly. The trail, carried foremost, was held up by two gunners, but, notwithstanding every precaution, the bridge swung from side to side, and the carriage acquired so much velocity, that the gunners who held up the trail, assisted by Captain Miller, lost their equilibrium, and the gun upset. The carriage, becoming entangled in the thong balustrade, was prevented from falling into the river; but the platform of the bridge acquired an inclination almost perpendicular, and all upon it were obliged to cling to whatever they could catch hold of, to save themselves from being precipitated into the current, which rolled and foamed sixty feet below. For some little time none dared go to the relief of the party thus suspended, because it was supposed that the bridge would snap asunder, and it was expected that, in a few moments, all would drop into the abyss beneath. As nothing material gave way, the alarm on shore subsided,

and two or three men ventured on the bridge to give assistance. The gun was dismounted with great difficulty, the carriage dismantled and conveyed piecemeal to the opposite shore. The rest of the artillery then made a détour, and crossed at a ford four or five leagues lower down the river.

A bridge of this description, over a considerable river between Lima and Cusco, is stated to have been 248 feet long, and 9 feet wide. The suspension-cables were attached on each side of the river to vast stone rings, or rather through holes worked in the living rock. This bridge was carried away in 1819, when the river rose suddenly to such a height as to reach the bridge.

The hill people in the Nepaul country use swinging bridges called Jhula, over rivers and torrents; these are formed of ropes of about 6 inches circumference, made of a species of grass called Baeeh. Some of these bridges are from 90 to 100 yards long, composed of 20 ropes, suspended across the river where it is most confined to a narrow channel, and where the banks are high. The ropes are either fastened to large trees felled and laid behind rocks, or pass over a wall erected for the purpose, and the ends fastened to large stakes buried in the ground, or to slabs of stone. The ropes have considerable droop, but the floor is made nearly level by being formed of slight frames of split bamboos, resembling a ladder, suspended horizontally to the main cables.

A Durdla, or sliding bridge of ropes, is a description of communication very commonly used. In the "Asiatic Researches," vol. xi., p. 492, we find the following account of a bridge of this nature on a branch of the Ala-

cananda. It is formed of three or four strong Munga ropes (Saccharum Munga) formed of a sort of grass, upon which a small frame, like a bedstead, is made to traverse by means of a couple of hoops. On this machine the passengers are seated, and conveyed to either side by ropes worked on both sides.

These expedients are all applicable to, and may be highly useful in, military operations, whether to cross unfordable rivers, ravines (nullahs in the East), precipitous places, or deep chasms; and either for men, horses, or cattle, by suspending them, in slings or cases, to traveller-blocks, which may be hauled from side to side of the impediment, as very commonly practised to this day in South America; and the author may well answer for the efficacy of an expedient by which, in shipwreck, he and his surviving companions passed over a furious surf, in which many of the people perished, to a precipitous rock, against which others were dashed to pieces. This, too, is the mode of communicating with the island of Gozo, at Malta, two ropes being used, and a cradle suspended to them.

In establishing temporary communications with beaches subject to surf, by which to land military dry (which might not be practicable by *beaching* the boats), the suspension-bridge principle may, obviously, be extremely serviceable in forming temporary wharves; spare masts and spars for the points of support, anchors and cables to stay them, ropes, tackles, and seamen are, in such cases, at hand. The spars for uprights should each be fitted with a *large* shoe, set a little above the point (Fig. 6, Pl. LXIV.), and the wharf completed. "The thing most curious and worthy a stranger's notice here (Island

of Bourbon) is the hanging bridge, which projects a great way into the sea; and by it both people and merchandise are shipped and landed, with all convenience and safety, even in the worst weather, when there is no approaching the shore in boats, on account of a prodigious high and dangerous surf against a steep, stony beach. It consists chiefly of four large masts, with iron chains to support them, and is about 30 feet above the surfacc of the sea; in bad weather, by means of pulleys and tackles, it can be raised much higher. Near the extremity is a ladder of ropes, by which people ascend from, and descend to, their boats."

The ruder rope-bridges here noticed are not cited as approved constructions; but to point out the various materials from which, on emergencies, ropes may be formed, and the circumstances under which such expedients may be found useful; and what has been shown is sufficient to indicate that, in almost all countries, materials may be discovered, or are known to exist, which may serve for these important purposes. There is no resource in nature or in art with which military men ought not to be conversant.

Fig. 3, Pl. LXIII., is a neat and simple application of the suspension principle, which may either be used on a large scale, with chains of sufficient strength, for artillery or any other weight; or, if for a foot-bridge, by using iron wire of thickness computed according to the weight and breadth of the impediment. A frame of timber, A B, in length one-third of the breadth of the space to be spanned, is prepared, and two cross-pieces, C D, nailed underneath, with grooves cut in their lower surfaces to receive the iron rods or wires. The frame is

then fastened to the chains or wires, in the manner shown in the figure, and the communication made good by beams and planks, or light frames, resting upon the bearers C D. If the beams or frames require to be strengthened in their respective centres, the cross-piece G may be placed under the middle frame, between it and the chain or wire; and the end beams suspended to the chains or rods, at E F. In all such bridges, lateral guys should be used, to prevent, as much as possible, a swagging or vibrating motion.

APPENDIX.

Report to Major-General Halleck, giving the results of Experiments on Blanket-Boats.

WAR DEPARTMENT, BUREAU OF U. S. MILITARY RAILROADS,
WASHINGTON, D. C., *August* 13, 1863.

To Major-General H. W. HALLECK,

General-in-Chief United States Army:

GENERAL:—I have completed my experiments on rafts of blanket-boats, with results quite as satisfactory as I had anticipated, and send you, with this report, a series of photographs illustrative of the several stages in the construction and operation.

I desired an opportunity of testing the utility of these simple structures on a practical scale—because, if successful, they would render possible military operations which have heretofore been declared impossible. They will render practicable the passage of a river in the face of an army of observation, without any previous preparation to indicate the point until within fifteen minutes of the commencement of the passage.

They will afford facilities for ferrying troops at the rate of 10,000 or more per hour, who, under protection of batteries on the re-entrant side of the stream, could effect a landing and obtain defensive positions before the enemy could concentrate to oppose them.

They will render unnecessary a suspension of operations, either offensive or defensive, to await the arrival of pontoon trains or the construction of bridges. A few India-rubber blankets, or pieces of water-proof canvas, strapped to the sad-

dles of the horses, are all that need be carried to afford transportation for an army.

In your very instructive work on the "Elements of Military Art and Science," you remark, that "General Taylor was unable to take advantage of the victories of Palo Alto and Resaca de la Palma, to pursue and destroy the army of Arista, because he had no pontoon equipage to enable him to follow them across the Rio Grande."

If General Taylor had possessed a few hundred India-rubber blankets, or even a lot of old tents, with rubber varnish, and had known how to use them, the pontoon equipage would have been unnecessary, and the calamity complained of would have been averted.

The unit of the system I call a blanket-boat, because an India-rubber blanket is its essential feature. With these units, boats, rafts, ferries, and bridges, can be constructed.

The blanket-boat consists of a rectangular frame, covered with a blanket. The dimensions of the frame are 64 inches long, 28 inches wide, and 18 inches high. The bottom and top rails of the frame consist of pieces two inches square, or two inches in diameter, connected by sticks one inch square or round, placed six inches apart. The cross-pieces in the bottom should be one inch square or round, and not more than three inches apart.

The sticks which connect the top and bottom rails are 17 inches in length. It was intended to make a round tenon on each end, $1\frac{1}{2}$ inches long and [illegible] inch diameter, to fit the holes in the rails, and a portable pocket instrument was invented to cut these tenons; but the workmen tell me they can get along faster by whittling the ends of the sticks with a pocket-knife; and as I generally adopt the suggestions of practical men, I have adopted theirs, and instead of the shoulder on the sticks, I slip a brass tube on the auger with which the holes are bored in the rails, so that it may not penetrate beyond the depth of an inch and a quarter.

For portability, the auger is made very short, not more than five inches in length. It has no permanent handle, but the shank is flattened and bent into a ring, through which a round stick is passed. A brass tube is slipped on the auger, which leaves an inch and a quarter of the lower end exposed, and

gauges accurately the depth of hole. A cap fits on the end, and prevents it from doing or receiving injury in the pocket. This convenient and portable little instrument is represented in photograph No. 69.

It is very important that the rails should be cut and the holes marked with patterns, so as to insure perfect uniformity and render all the parts interchangeable. The pattern may be a thin strip of brass, tin, or steel.

The frames were tied at the corners with pieces of tarred rope, and the blankets attached to the frames with strands of the same material, passing through eyelets in the blankets at distances of six inches apart. The top edge of the blanket should be at least one-fourth of an inch below the bottom of the top rail, so as to permit cords to be passed between, to connect the frames together in forming rafts.

TIME REQUIRED TO CONSTRUCT A BOAT.

Forty men, without previous experience, made fifty boats in ten hours, under unfavorable circumstances. The material was all split out from trees, and the time of preparing the material is included. With round sticks, or with material previously prepared, the time would be reduced one-third, and, with practice, one-half. A brigade of engineer troops, properly drilled, could be relied upon to turn out one boat to every two men in four hours. It is best for the men to work in pairs. No tools are required in putting the frames together, except a small rough stick of wood, or a stone, to be used as a mallet.

Forty men, working in pairs, with the material placed in front of them, put together twenty frames in sixteen minutes, and several of the pairs finished their frames in eight minutes.

From five to eight minutes were consumed in tying on the blankets.

From two to four minutes were required to untie and take off blankets.

Five minutes were found sufficient to take frames apart and pile the sticks.

The weight of a frame, constructed of split green oak, the sticks being unnecessarily large, was 65 lbs.

The weight of one kind of blanket experimented upon was 7 lbs., and of another and better kind, 10 lbs.

USES OF SINGLE BOATS.

A single boat has a superficial area of 12.4 square feet, and requires a weight of 387 lbs. to sink it six inches. Two men of ordinary weight, with arms and knapsacks, would not quite sink it to this depth.

The boats can be used singly by those who are accustomed to canoe navigation, and even those who have had but little experience in boating can use them, if not excessively awkward. Two men should sit flat on the bottom, facing each other, and use the paddle.

Single boats may often prove of great value for scouting purposes. Two scouts can, in half a day, make a boat in the woods, which can be carried with them many miles without inconvenience; and by this contrivance they are possessed of a means of advancing or of eluding pursuit which may often prove invaluable.

Four blanket-boats, tied together, form a very stable float, which may be paddled, poled, or rowed, with great facility. Rowlocks are readily made by boring holes in the top rails and inserting pins. A float of four boats was used in paying out the rope to form a ferry, and answered perfectly.

FERRY OF BLANKET-BOATS.

A raft of twenty-four boats was experimented upon in crossing a ferry. The ferry was formed by stretching two ropes across the stream, at a distance apart of about 100 yards. One of these ropes was intended for the loaded rafts, the other to return the empty ones. In establishing the ferry, a place should be selected for the crossing where the water is shallow near the shore, so that while the raft is pushed from one rope to the other, the men may wade in the water, and jump in or out without stopping the raft. In this way, with a movement

of two miles per hour, troops may be thrown across a stream at the rate of 10,000 men per hour, allowing between rafts intervals equal to their length. With four ropes, 20,000 men can be thrown across in the same time.

If the stream be supposed 600 feet wide, the number of single boats, of the dimensions given, required for a capacity of 10,000 men per hour, will be 900. If the current is rapid, the ropes must be supported by anchors and buoys; and if the stream is too wide to permit ropes to be stretched, oars, poles or paddles must be used.

For the transportation of troops, no flooring or decking is required, and the rafts are so steady that men may sit or stand at pleasure. A raft of twenty-four boats was packed with sixty-four soldiers, with guns and knapsacks—a load which could be safely carried in moderately smooth weather; but so much time is lost in getting the men to pack, three to a boat that it is better to limit the number to two only.

RAFTS OF BLANKET-BOATS FOR ARTILLERY.

The possibility of using such rafts for artillery having been questioned, I determined to settle it by direct experiment. A raft was made of thirty boats, six lengths and five widths. Across the middle of the six tiers of boats, six round sticks were laid and tied to the top rails. Across these longitudinally were placed two sticks, each 26 feet long, and on these again 50 railroad ties, to form a floor. The structure was very stiff, and no difficulty was presented in running the artillery (twelve-pounders) on and off by hand. By extending the raft to nine lengths, the horses could be driven on with the piece, without detaching. I found, by measurement, that the distance from the head of the front horse to the rear of the hind wheel was forty-three feet. Another raft, in addition to the artillery men, contained twenty infantry, and the weight of the ties which constituted the flooring was equivalent to thirty-three men more. In using this system, poles or fence rails would constitute the flooring, where boards or plank could not be procured.

Cavalry can cross on the rafts by letting the horses swim, and holding the bridles. I was anxious to test this experimentally, but could find no suitable place.

OBJECTIONS.

The objection to the blanket-boat is that the blanket is easily abraded or torn, if it comes in contact with any hard body, such as gravel, sand, sticks, or stones; for this reason, the men should get in and out of the rafts in one foot of water. The blanket should be protected by rounding all the sharp corners and edges of the frames; and if they are to be frequently used, an ordinary-sized blanket or piece of canvas should be placed over the bottom, with hay, straw, grass, or leaves between, to form a cushion to protect the inner blanket where it is in contact with the bottom rails.

When rubbed, if the blanket is dry, it can be rendered water tight almost instantly by painting the parts with gum shellac dissolved in alcohol, or, if slightly torn, a piece of cloth dipped in the varnish may be pasted on the place. For more serious rents, patches coated with India-rubber cement should be used. These articles can be carried in canteens without inconvenience.

BRIDGE OF BLANKET-BOATS.

In streams where the current is not very rapid, and where drift can be disposed of by booms or other arrangements, a continuous bridge may be formed of blanket-boats in as short a time as is required to place a pontoon-bridge. For this purpose, a rope should be stretched across the stream, anchored at short intervals, and the line of boats tied to the rope. The bridge would be formed in rafts of from ten to twenty lengths, and not less than eight widths, and would be put in position with great rapidity. The longitudinal timbers which compare with the balks of a pontoon-bridge should break joints, and should be in five rows. The flooring, in the absence of plank or boards, may be of poles or fence rails. Artillery should keep in the middle; infantry may march close to the sides. The capacity for support, with six inches displacement, will be 583 lbs. per lineal foot, or 9,494 lbs. to 18 feet, which corresponds to an ordinary bay or interval of a pontoon-bridge on which the maximum allowed weight is 7,000 lbs. Infantry could pass eight abreast without danger. A twelve-pounder

gun would cause a deflection of less than four inches. Cavalry could pass four abreast.

If it should be considered desirable to transport the frames and blankets, the weight for 600 feet of bridging would be 48,000 lbs., which is about the weight of the pontoons in the French bridge equipage. Nothing would be saved, therefore, in transportation, but the cost would be only about one-third the cost of the pontoons, with greater capacity of flotation. It would, however, offer greater resistance to the current than the pontoon-bridge, and would not be so well adapted to rapid streams.

The chief excellence of the blanket-boat system consists in the extraordinary rapidity with which bridges and ferries may be extemporized from fence rails, poles, split wood, or débris of buildings. With 2,000 blankets, Lee should have been able to build two bridges and cross his whole army over the Potomac at Williamsport, with all his impedimenta, within 24 to 36 hours after arriving on its banks.

BARREL ANCHOR.

One of the most convenient modes of constructing anchors for floating-bridges, in the absence of a regular equipage, consists in taking empty barrels, one end of which has been removed, boring six or eight two-inch auger-holes around and a short distance above the bottom, into which stakes of tough wood are driven. A rope is then fastened to the inside, the barrel filled with stones or gravel, and sunk.

The military operations of our armies are usually carried on either in districts of country which are thickly inhabited and with numerous buildings, or amongst sparse populations where forests cover a large portion of the land. In the former case, flooring for bridges can be procured by taking up the planks and boards on the floors of barns and houses. If forests are in close proximity, corduroy flooring can be used. In either case, the transportation may be reduced to the blankets, 6,720 lbs. for 600 feet of bridging, which can be carried on the saddles, or to 48,000 lbs. if frames are transported, requiring sixteen wagons instead of sixty-seven, as compared with the ordinary pontoon trains.

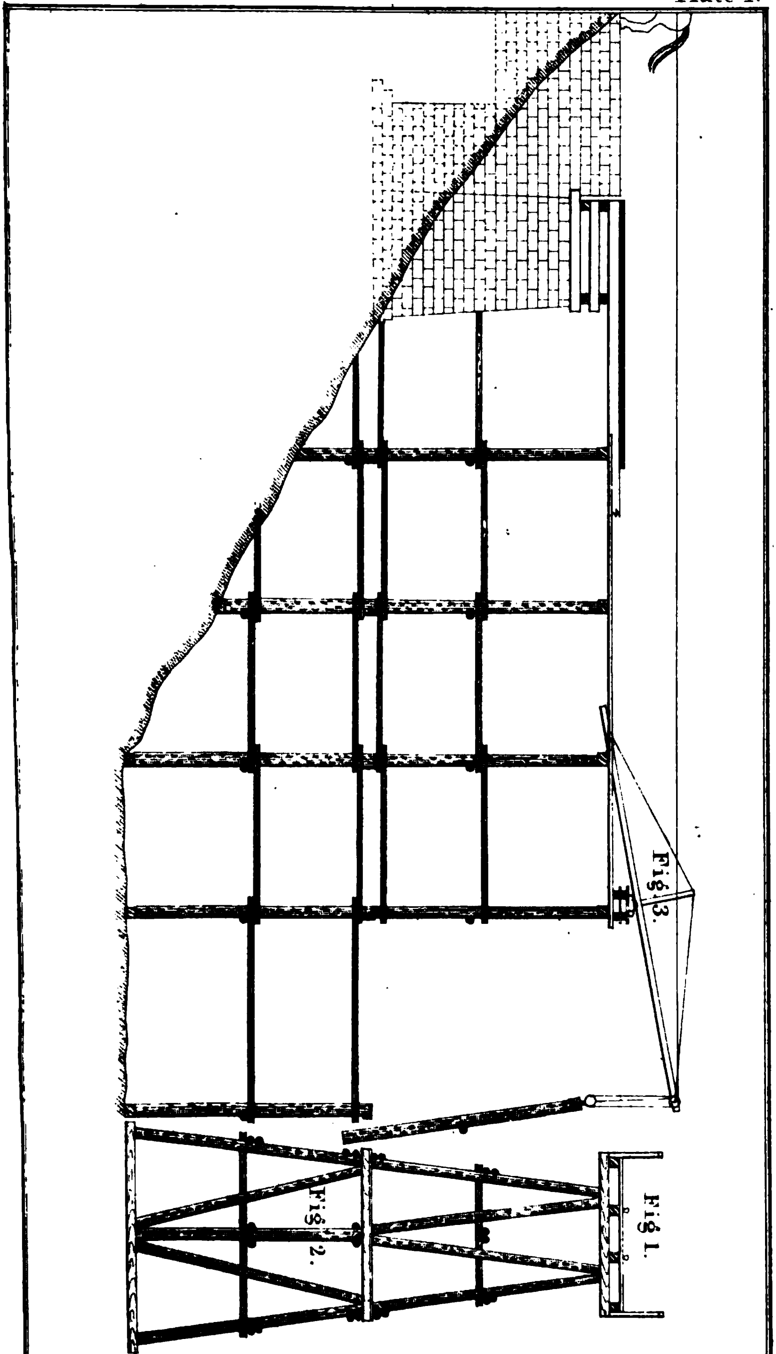
Practically, the best arrangement will be to attach permanently to the blankets the strings which are required to secure them to the frames, and to roll inside the cords which hold the frames together, and tie the transverse timbers. The blankets and cords will weigh from eight to eleven pounds, and this, with a few anchor-ropes, is all the transportation that is absolutely necessary. Every thing else can be found near the proposed bridge or ferry.

Respectfully submitted.

H. HAUPT.

BRIDGE CHORDS.

It is proper to observe that the dimensions of the chords given for military truss bridges are adapted to spans of about 100 feet. As the cross section of the chords should increase nearly as the square of the span, a bridge of 150 feet span should have 2¼ times the cross section in the chords, that a bridge of 100 feet span would require, and the arches should be in proportion. This results from the fact, that the strain upon the chords is directly as the span and also directly as the weight, but the weight being nearly as the span, the strain will be as the square of the span. This observation is made by the author, in consequence of information that, after he was relieved from the charge of the United States Military Railroad Department, an attempt was made to construct a long span of the military truss bridge, without increasing the number of chord planks.



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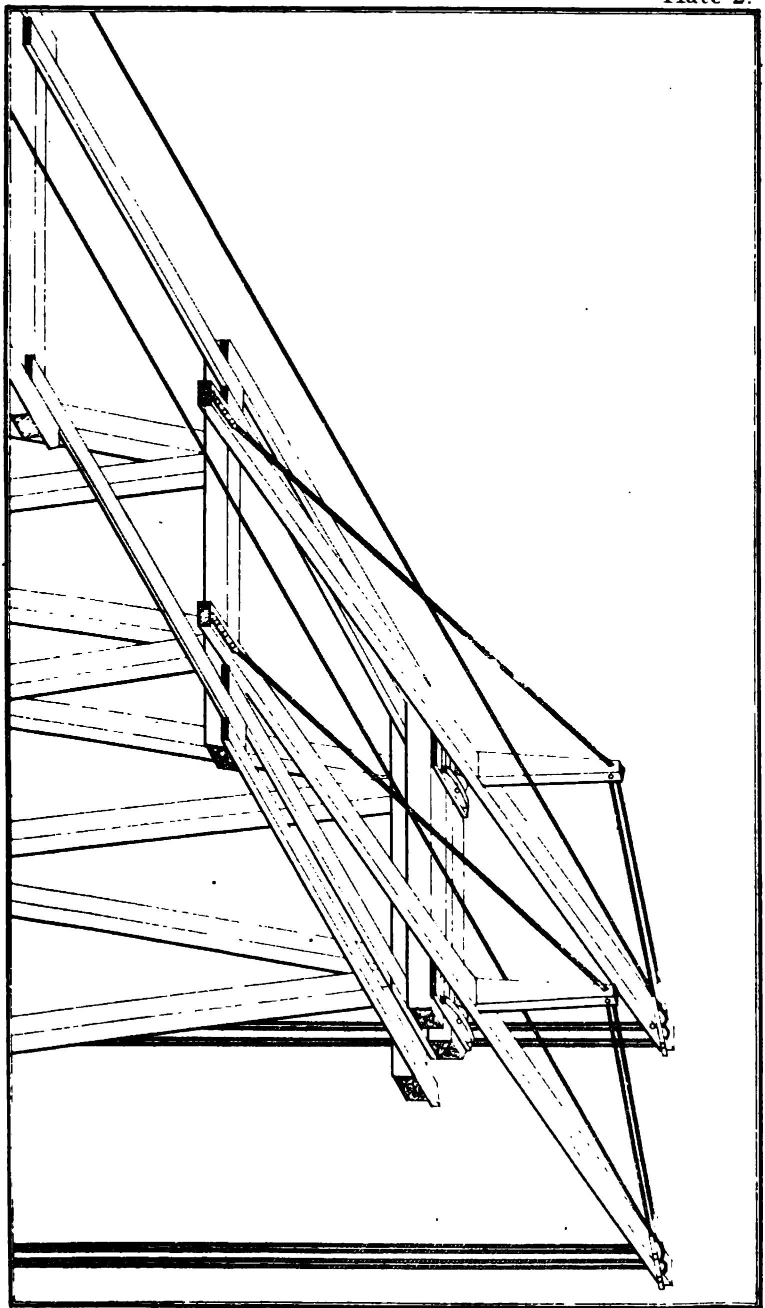

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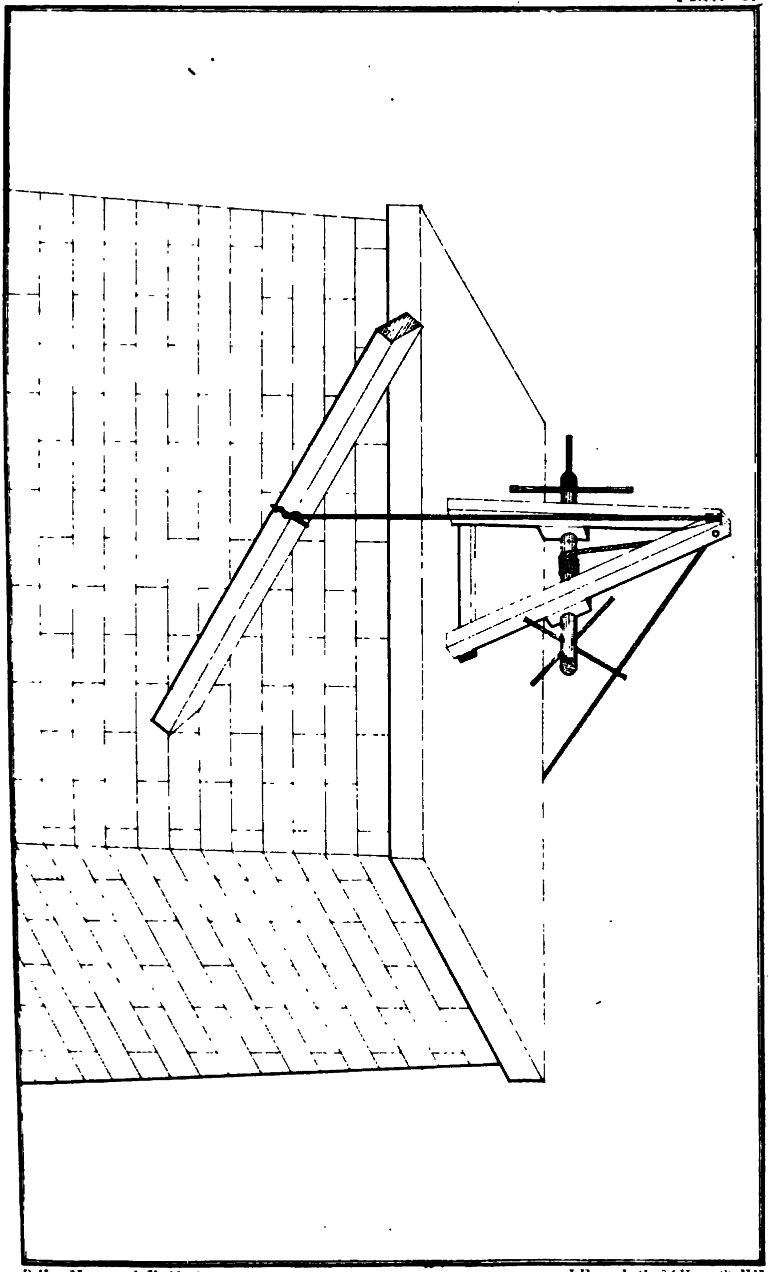

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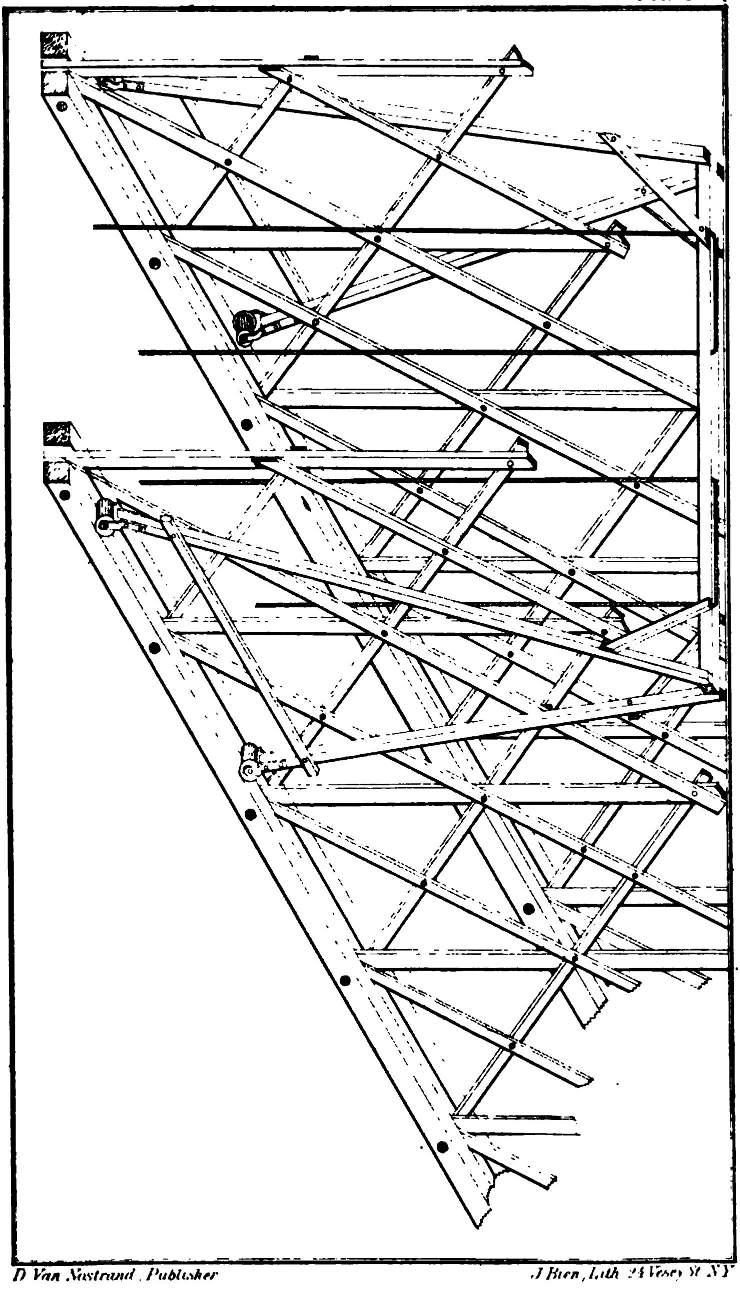

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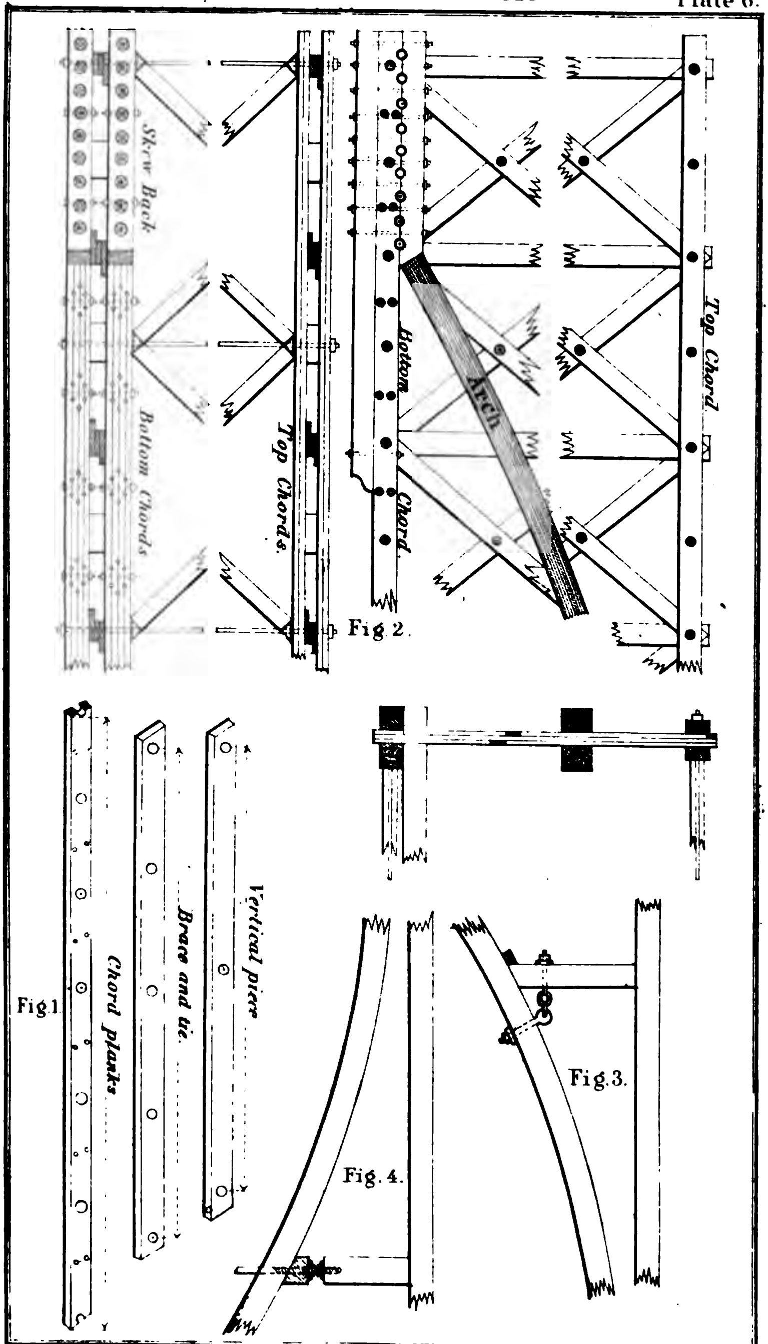

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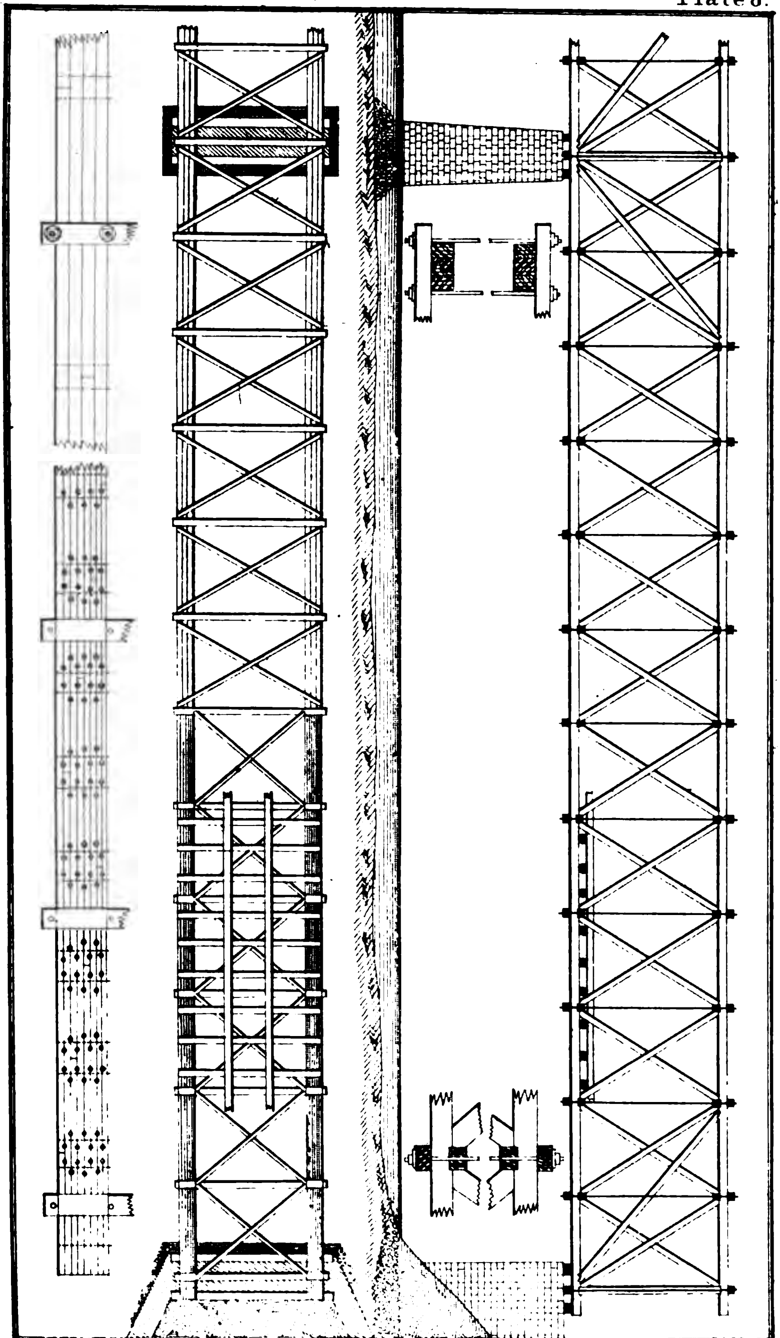

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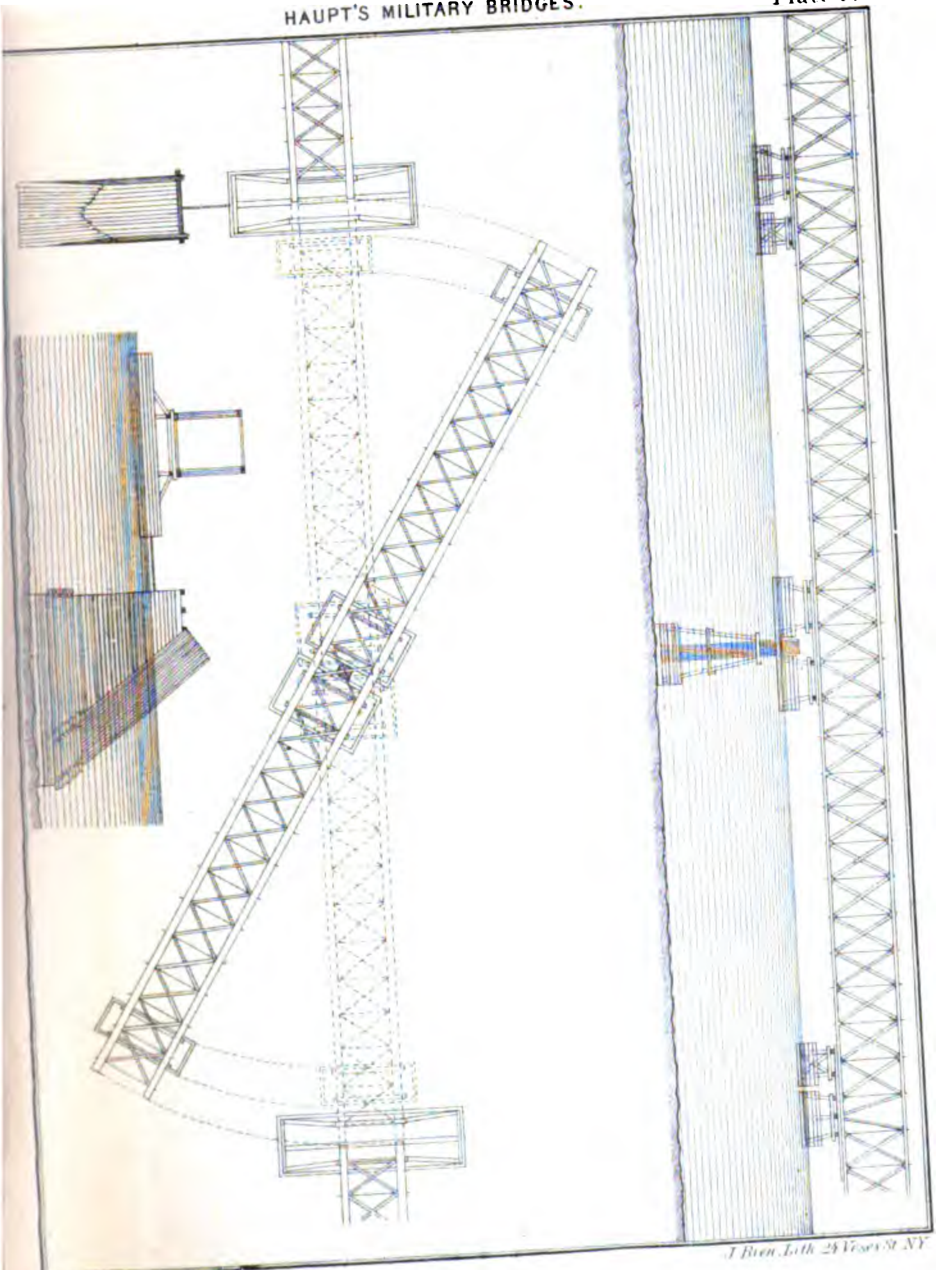

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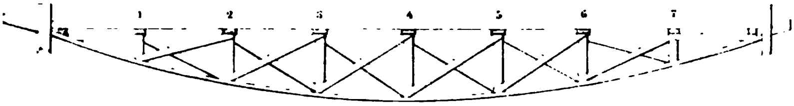

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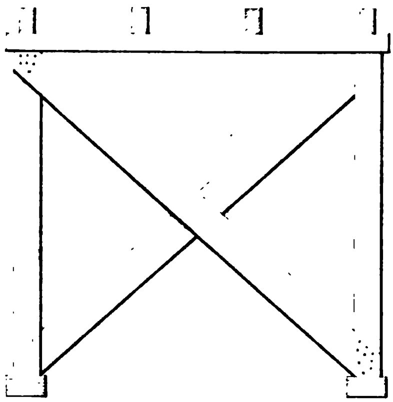

Section at 4

Fig. 2.

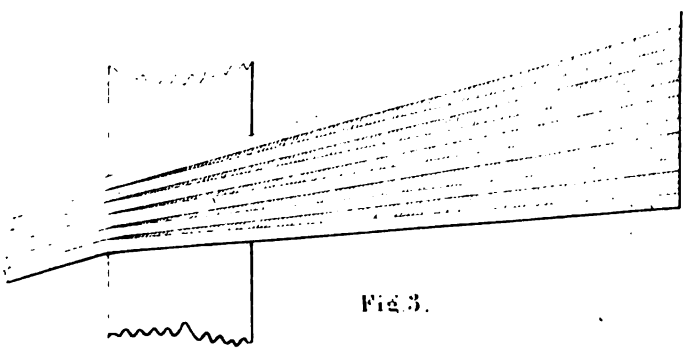

Fig. 3.

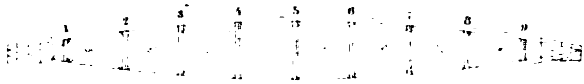

Fig. 1.

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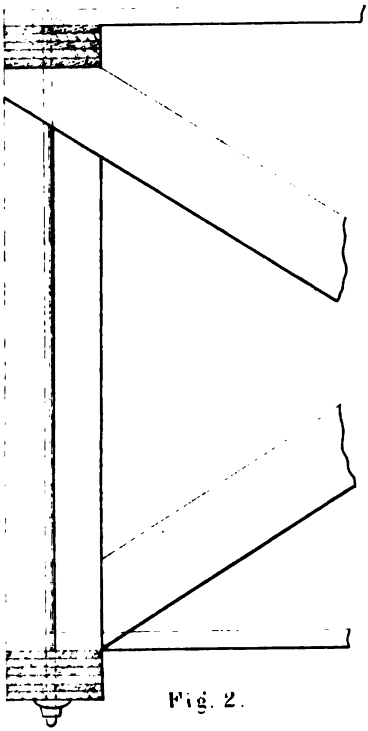


Fig. 2.

Section at 9.

Fig. 3.

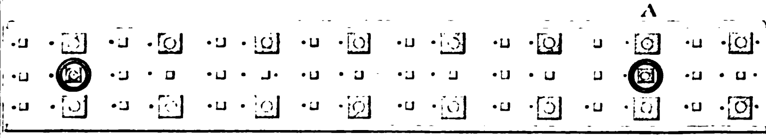
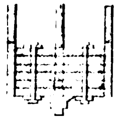


Fig. 4.

Fig. 5.



Section at A.

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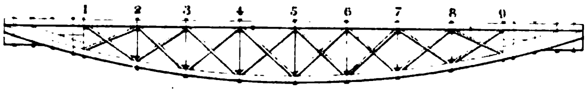

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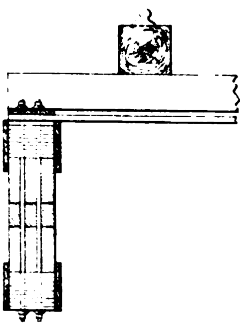

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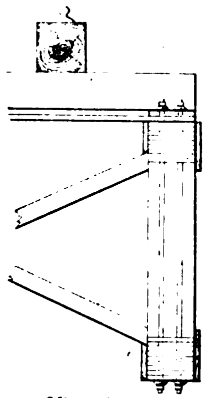

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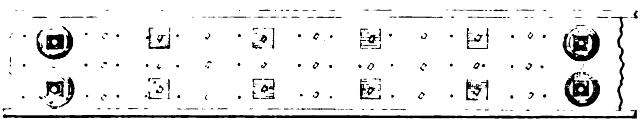
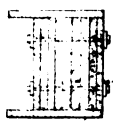


Fig. 4.



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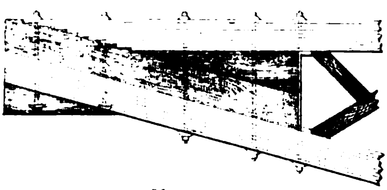

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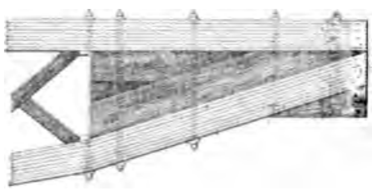

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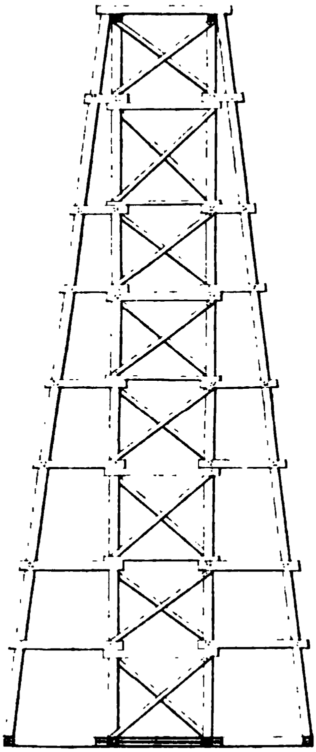

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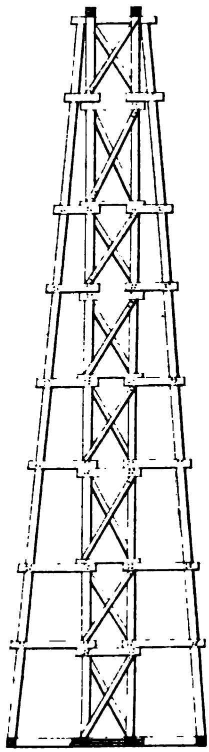

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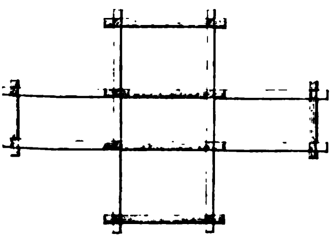

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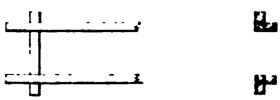

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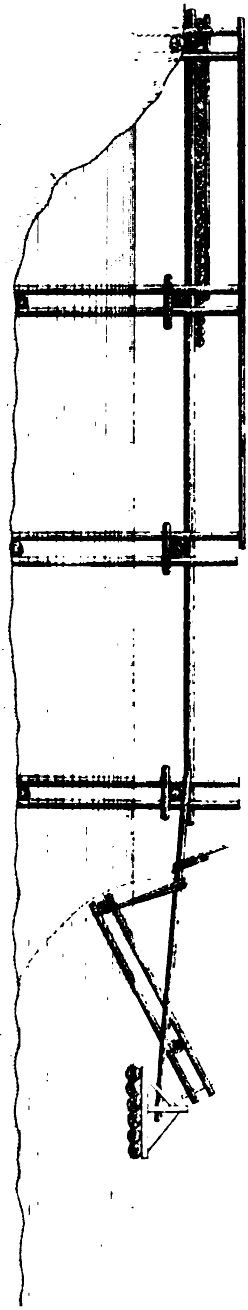

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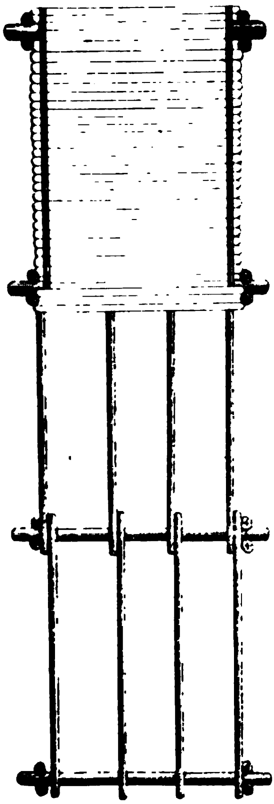

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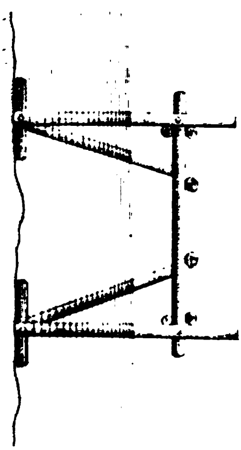

Fig. 3.

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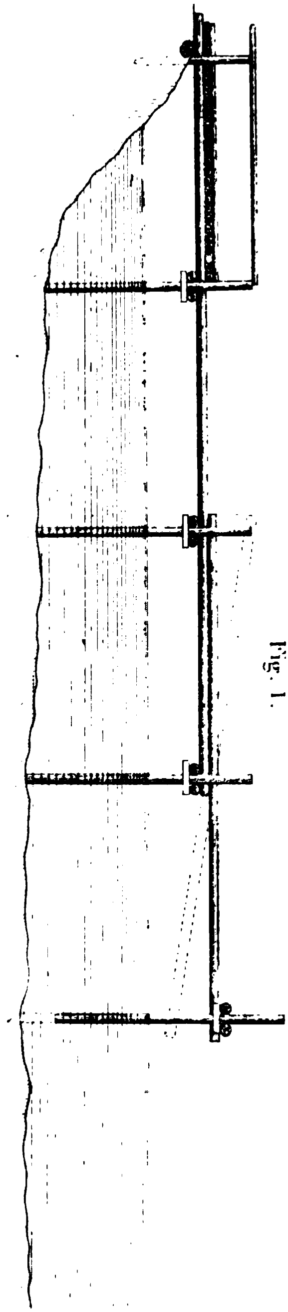

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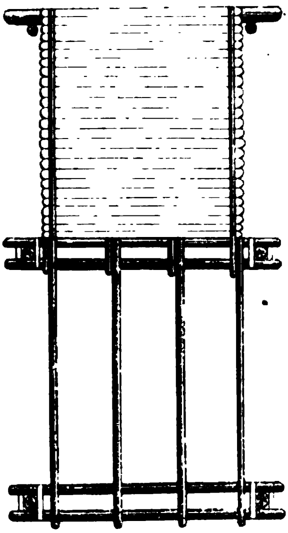

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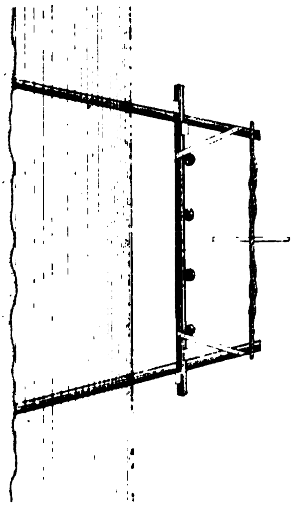

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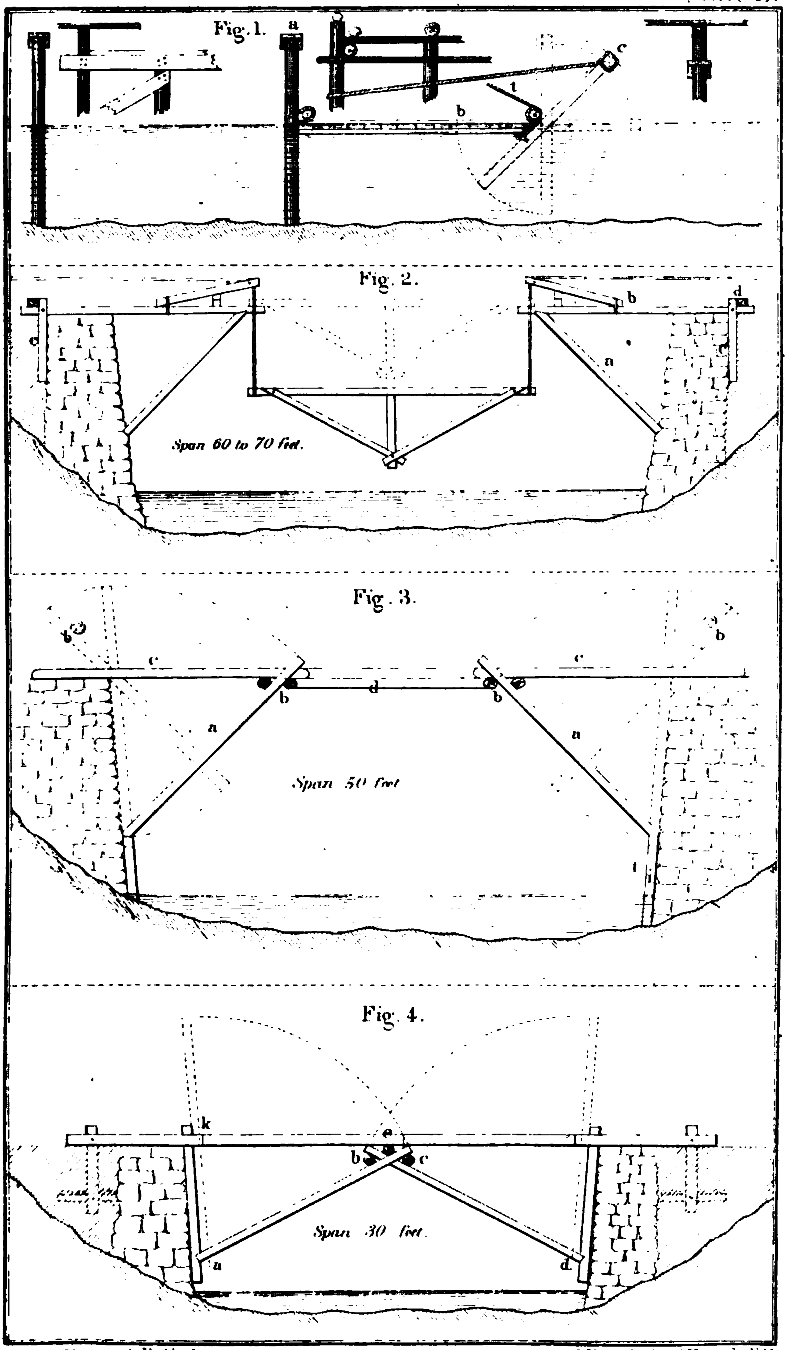

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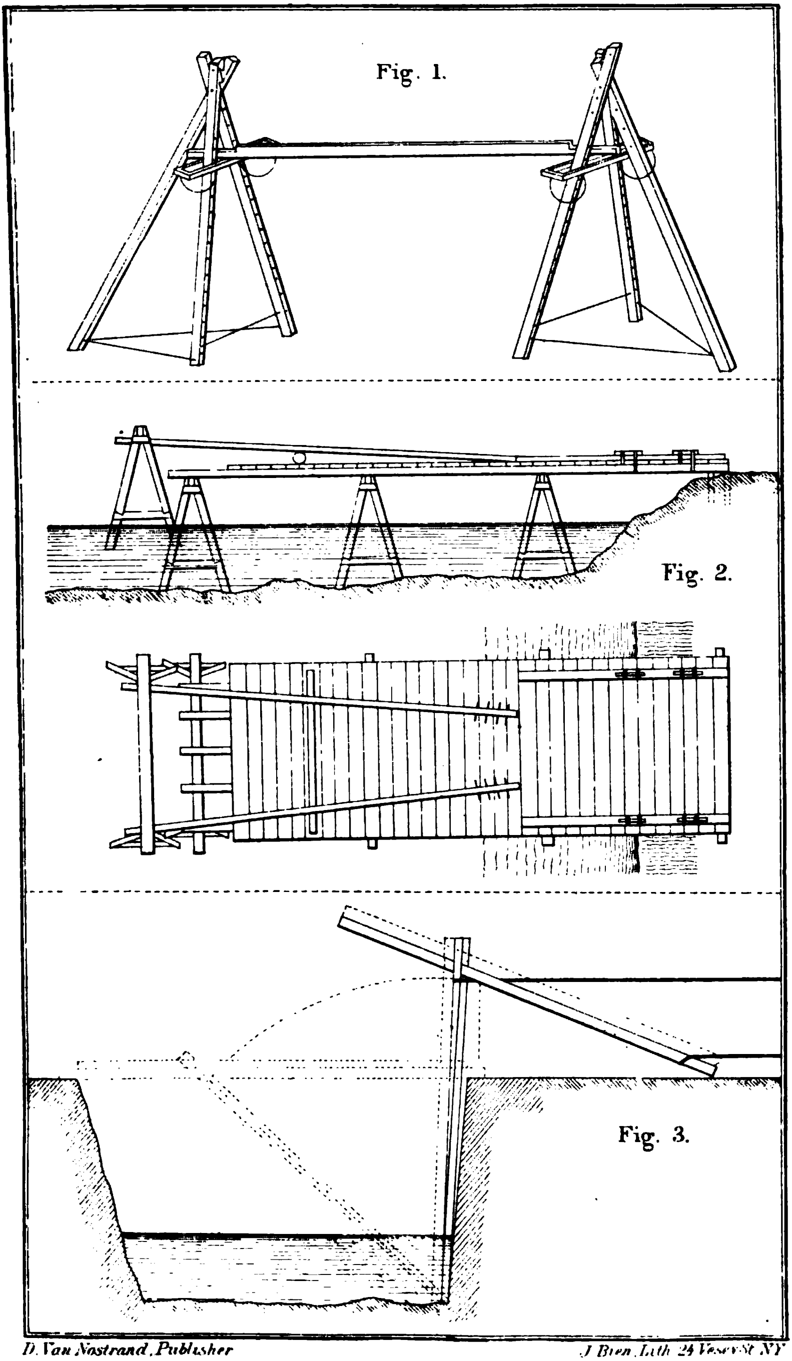
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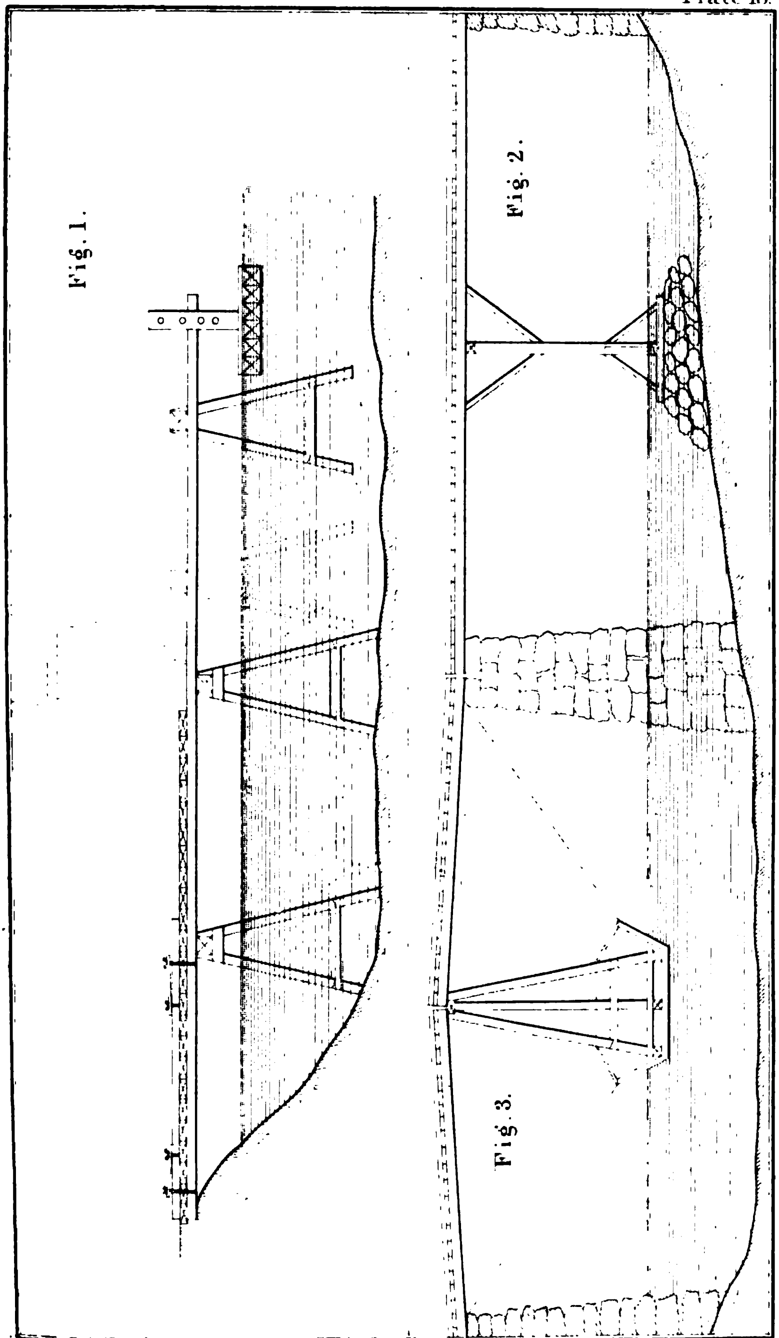

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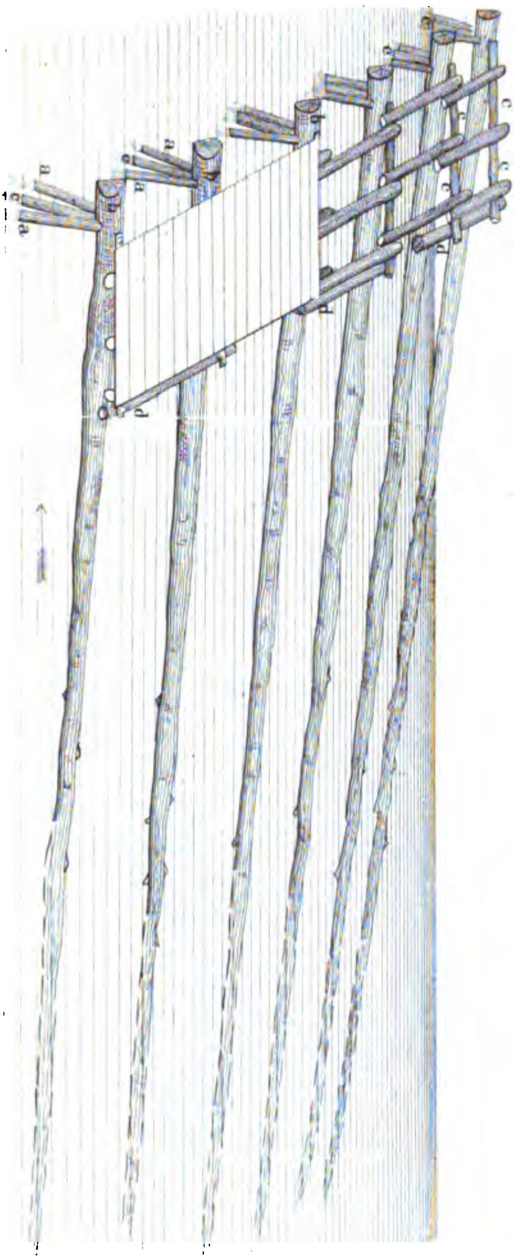

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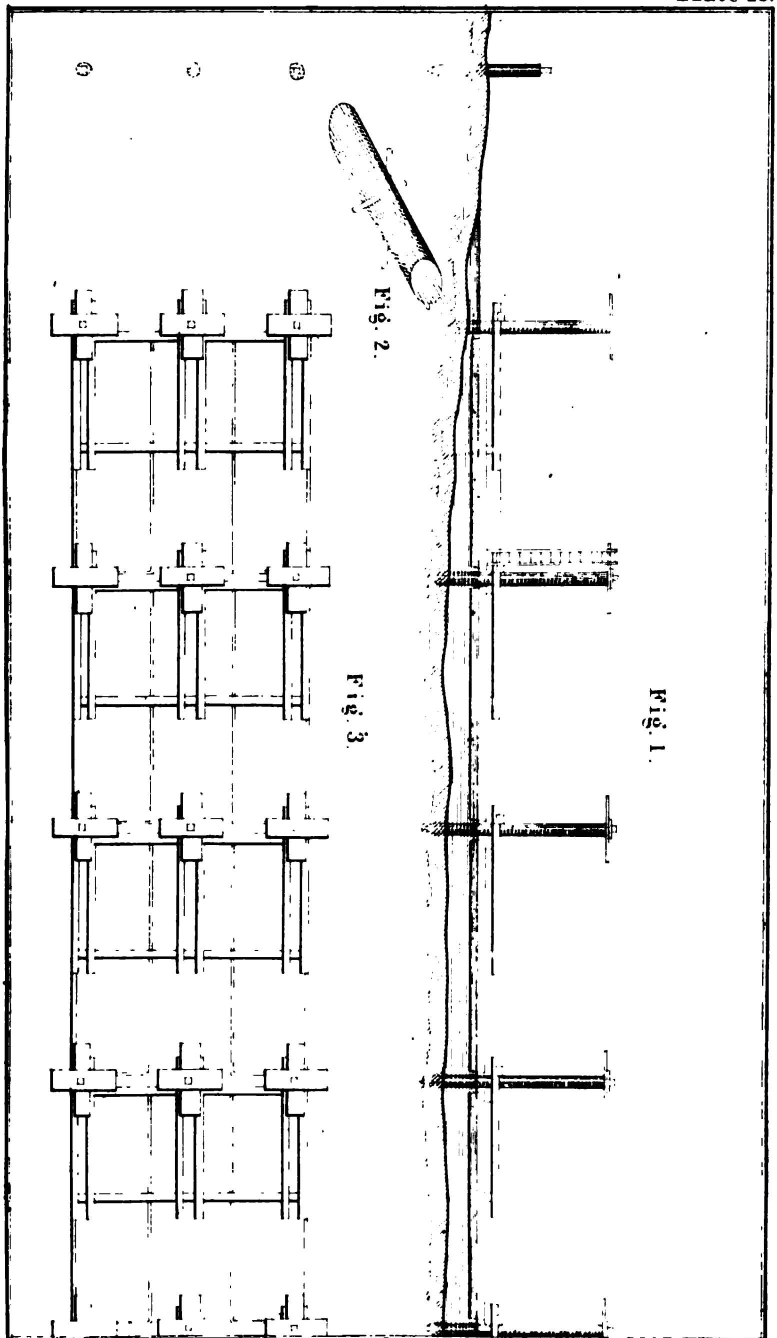

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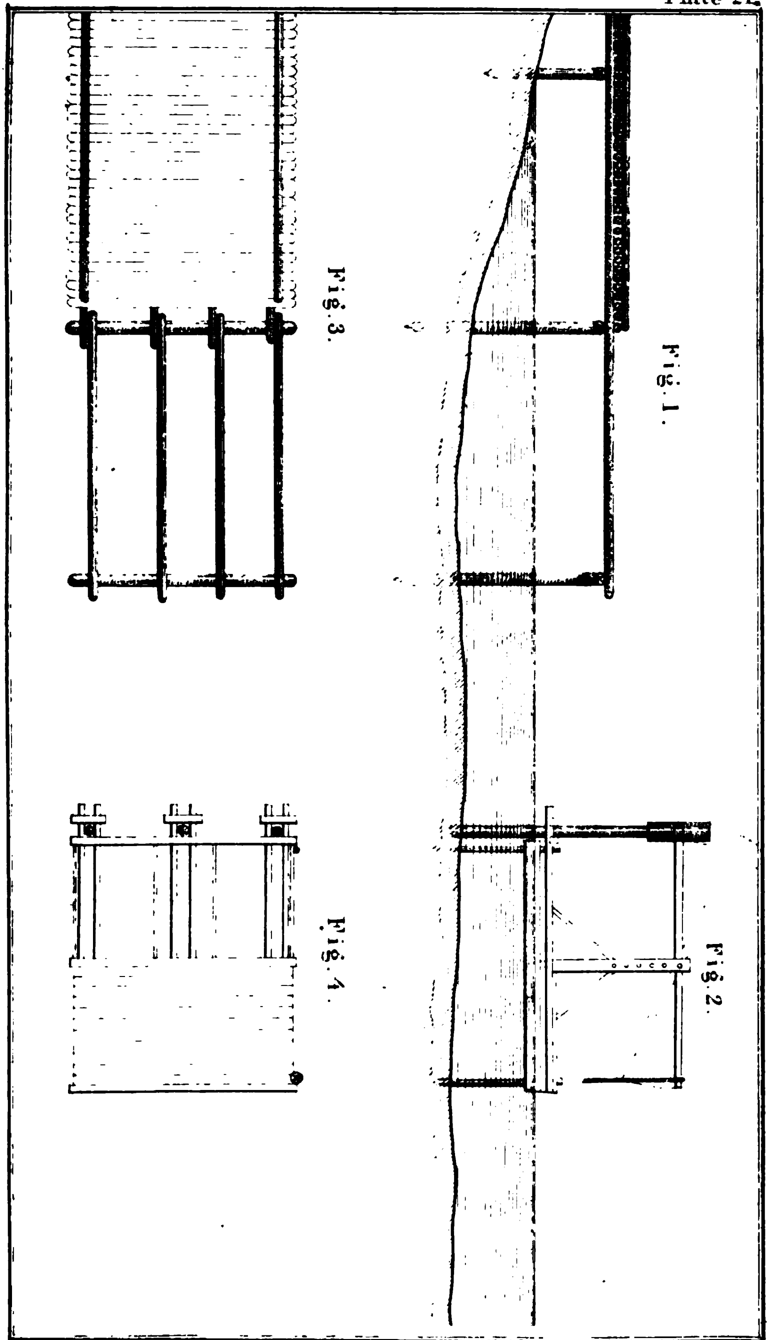

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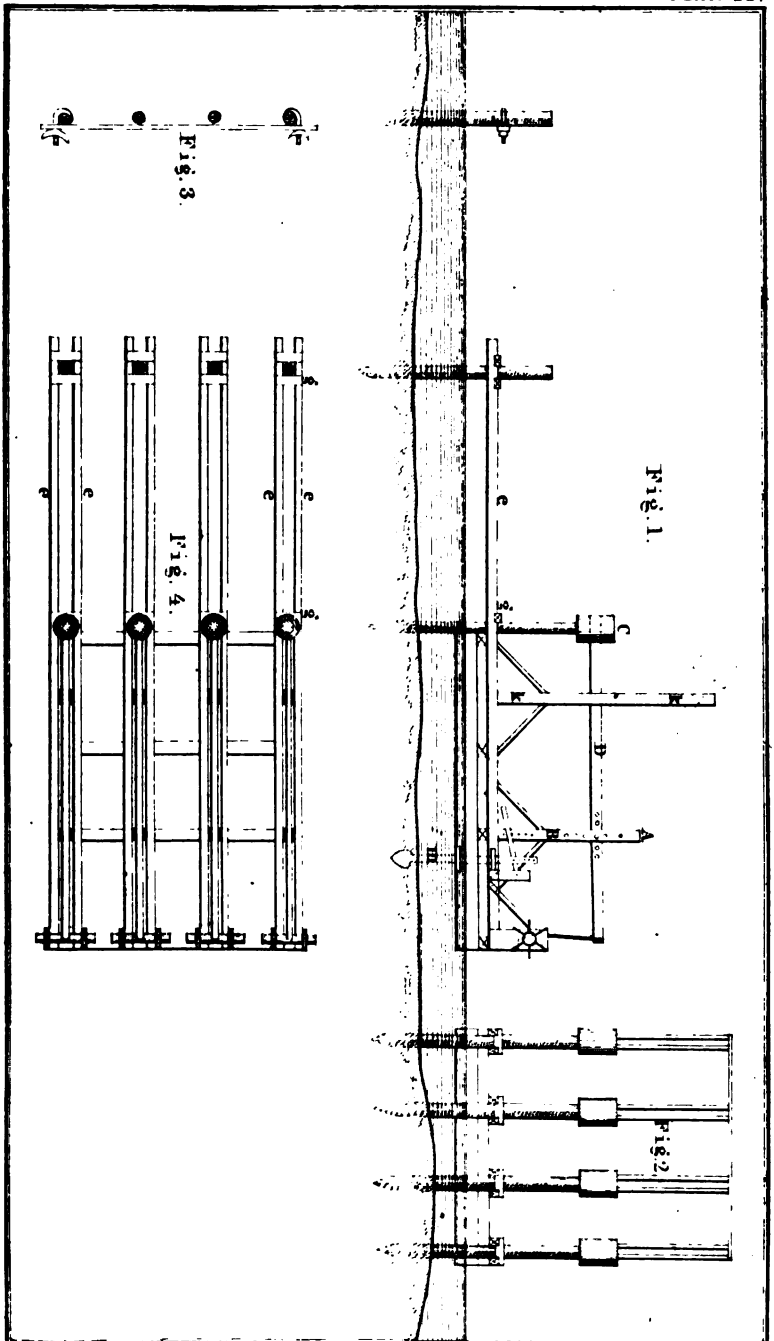

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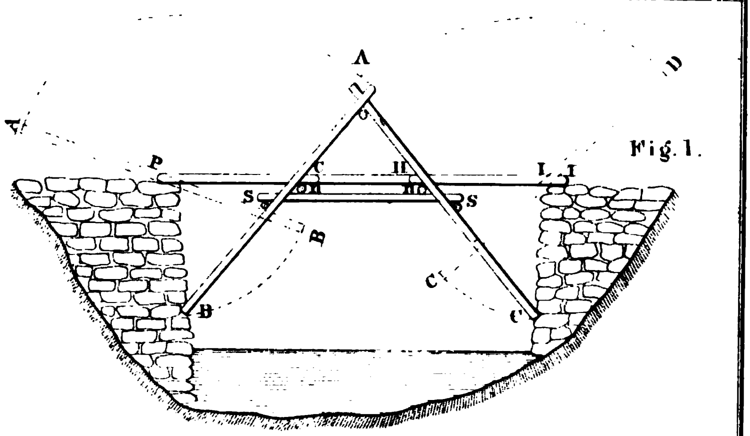

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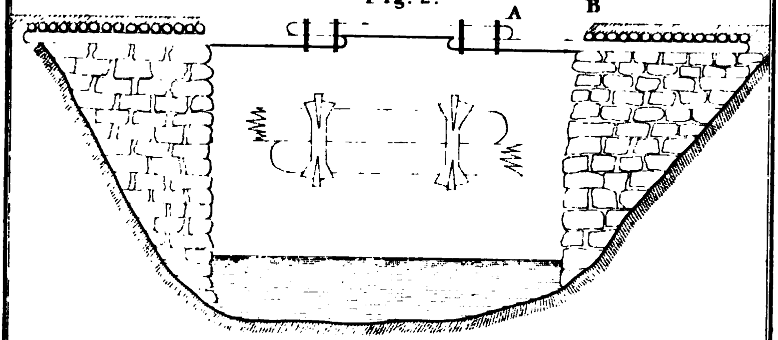

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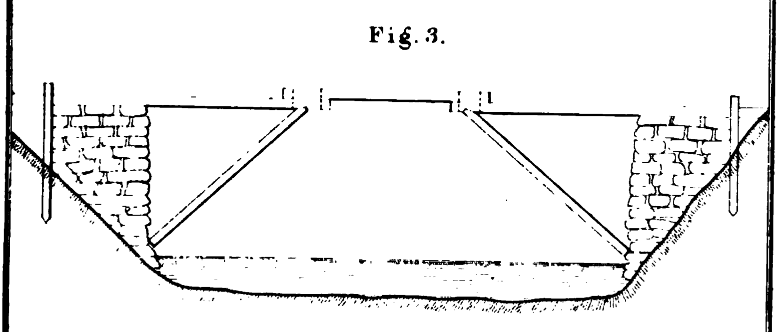

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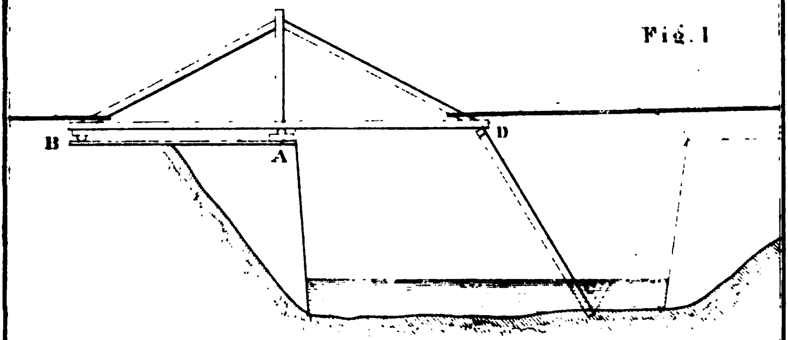
Fig. 1



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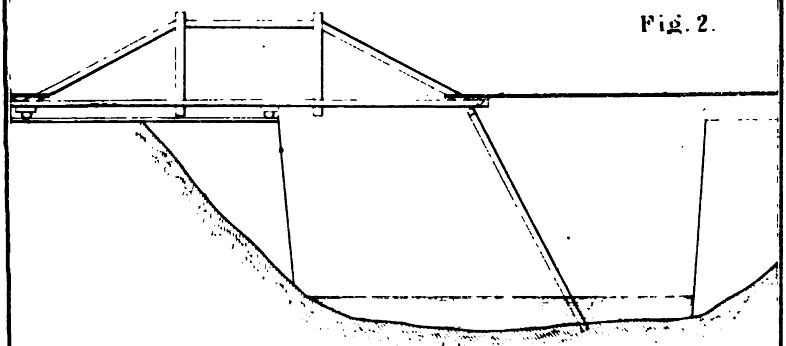

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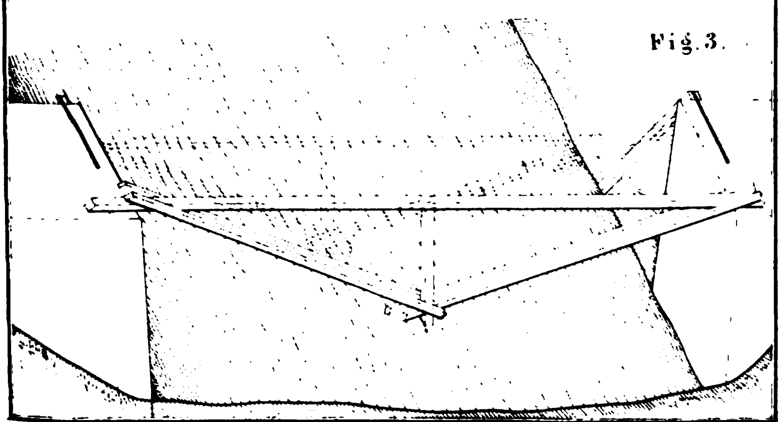

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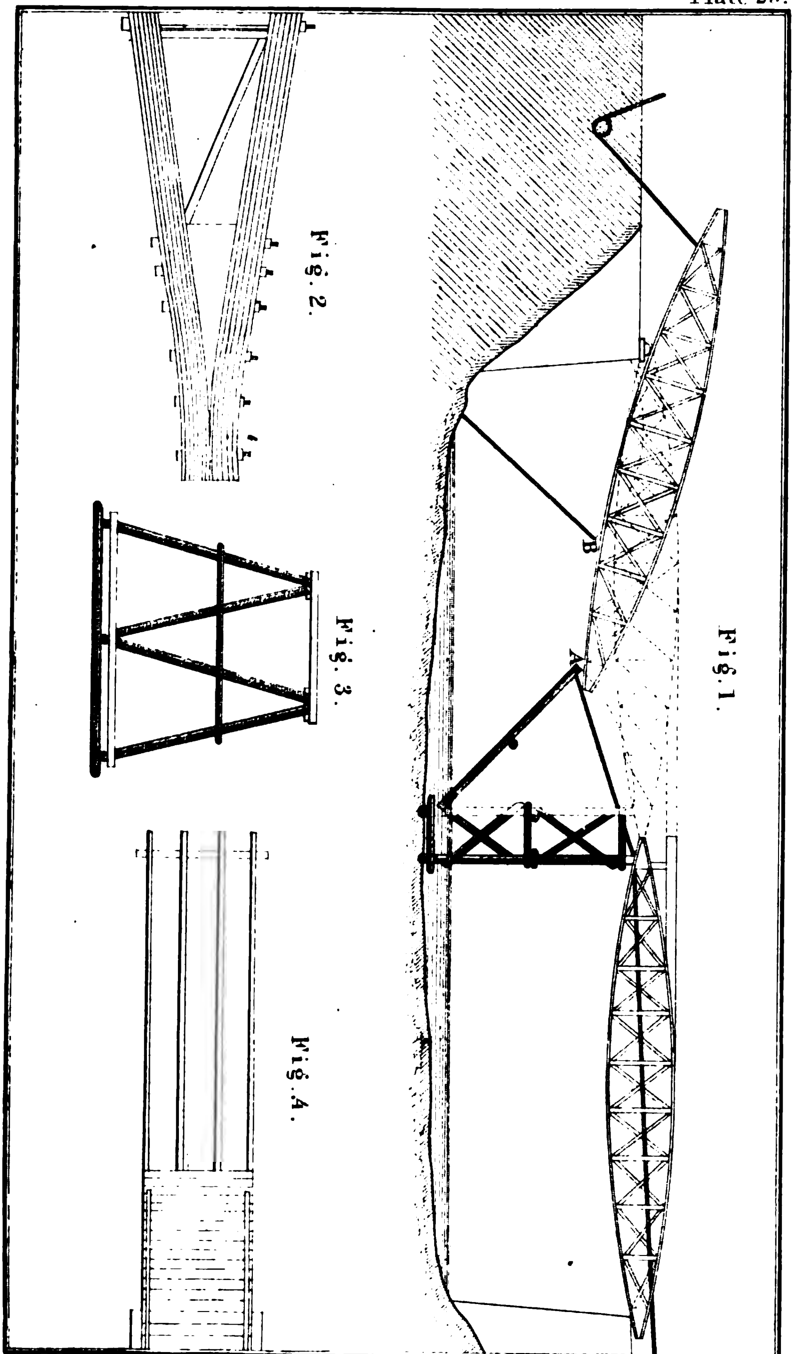

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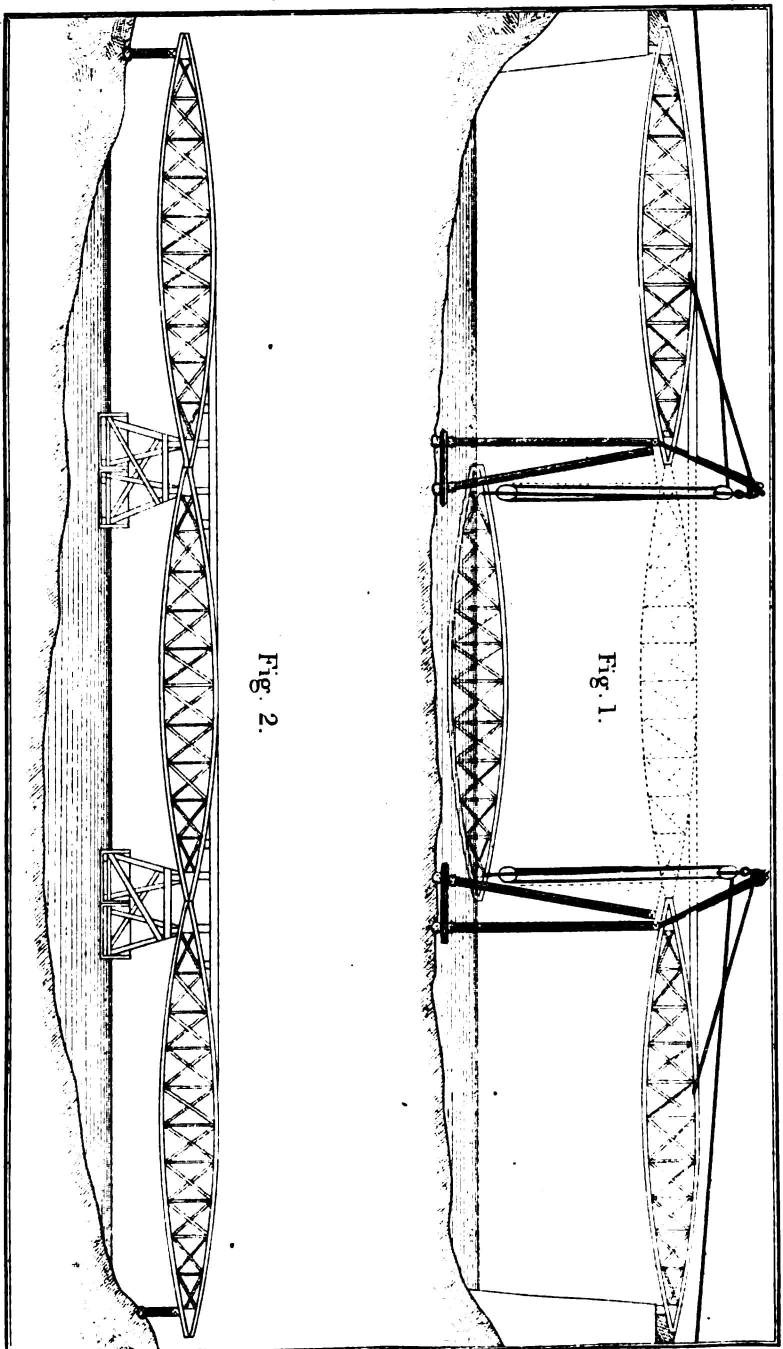

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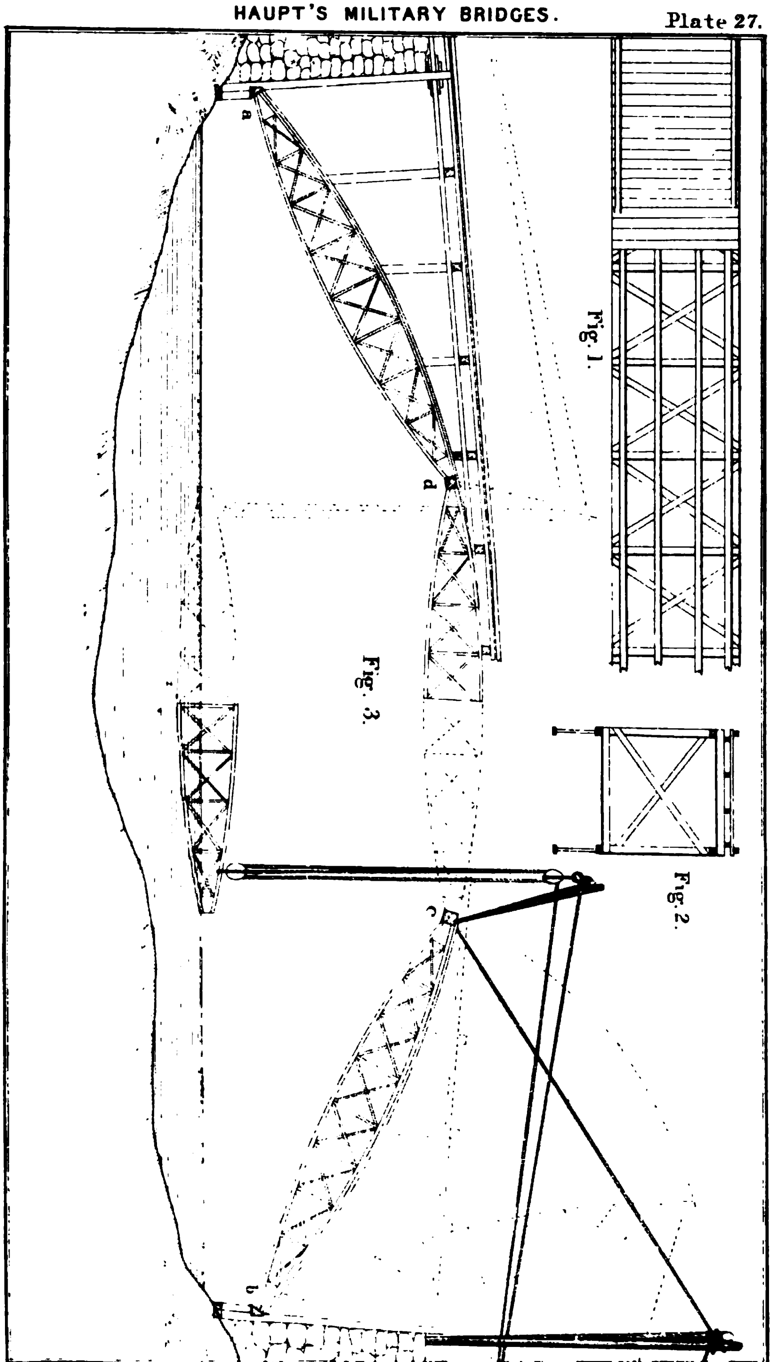

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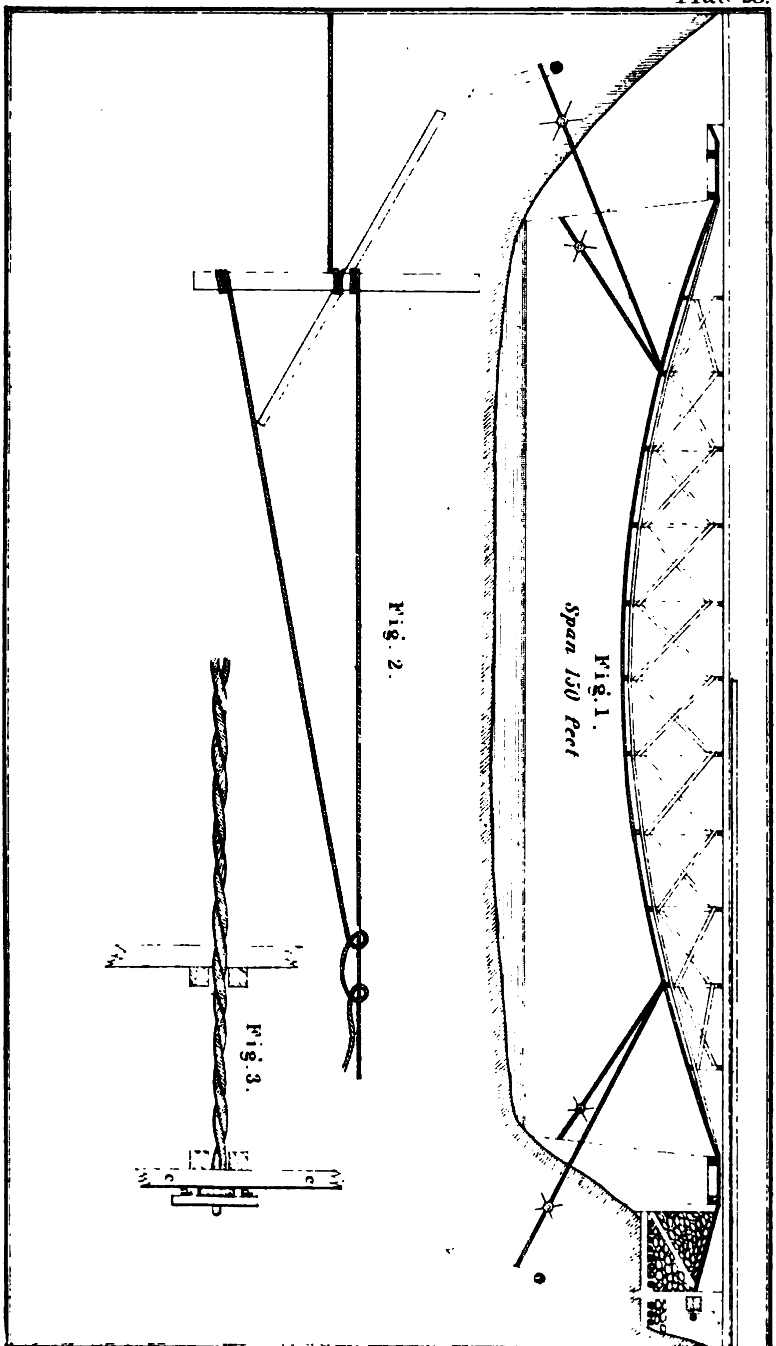

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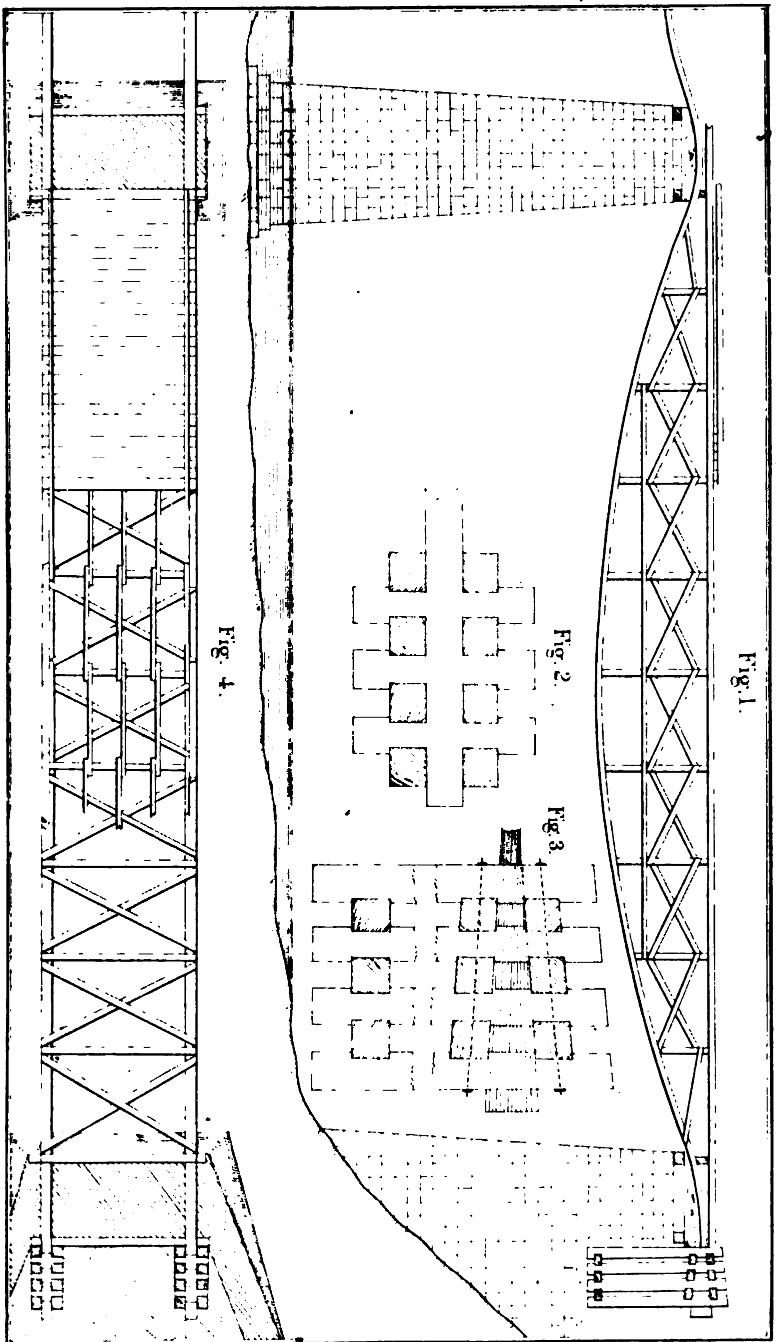

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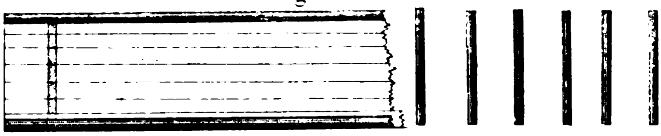

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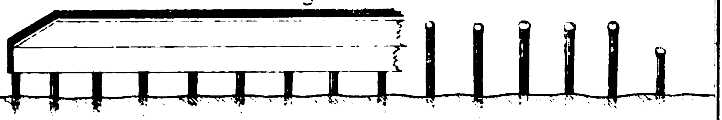

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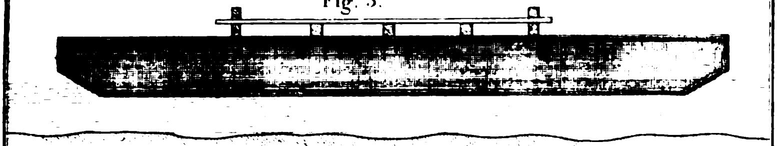

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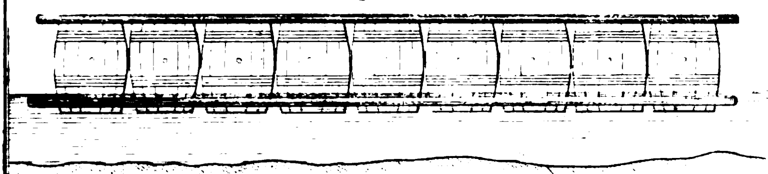

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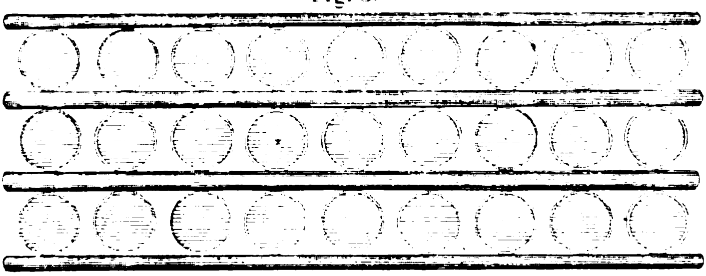

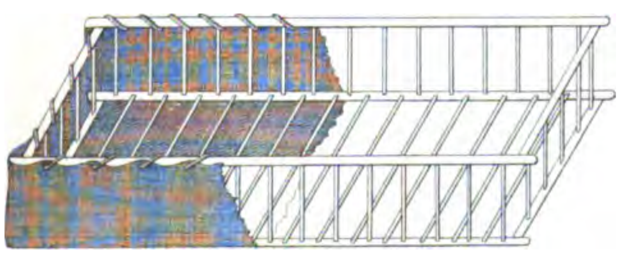

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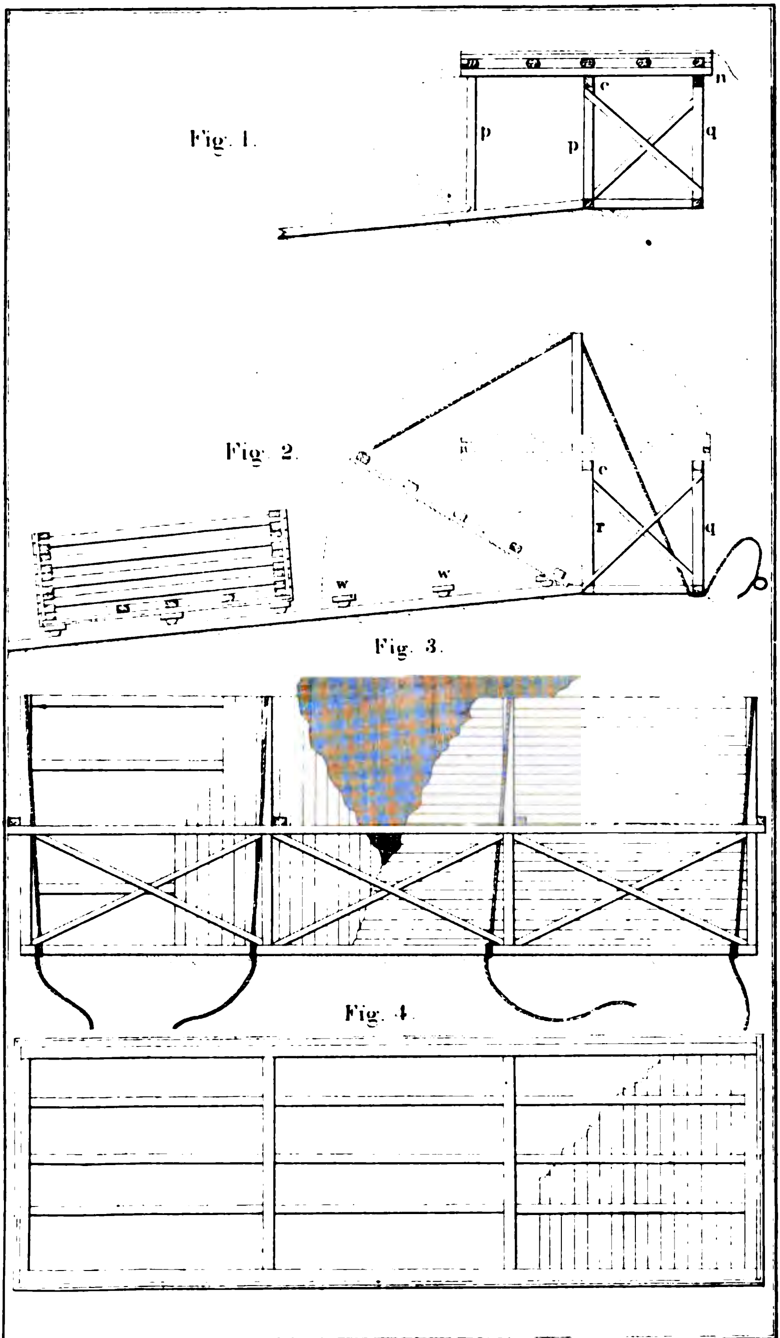

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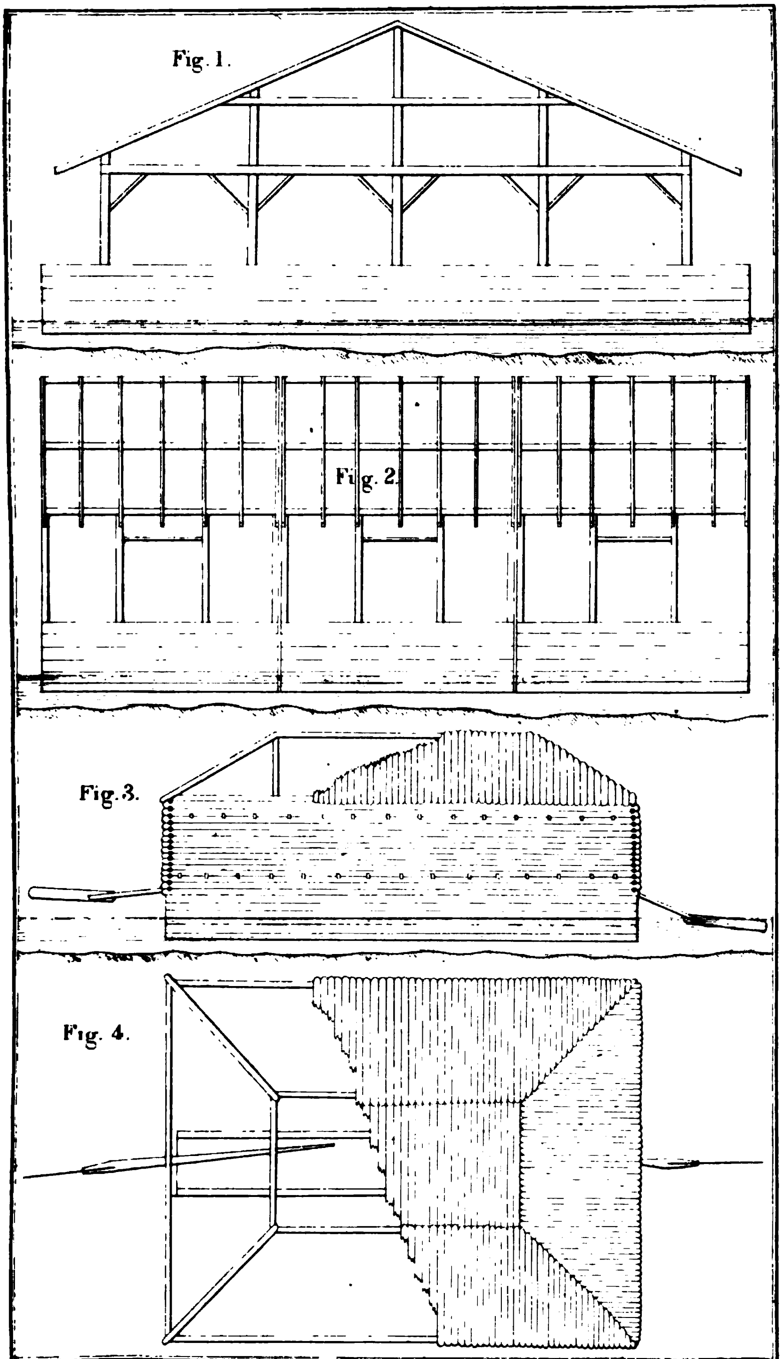

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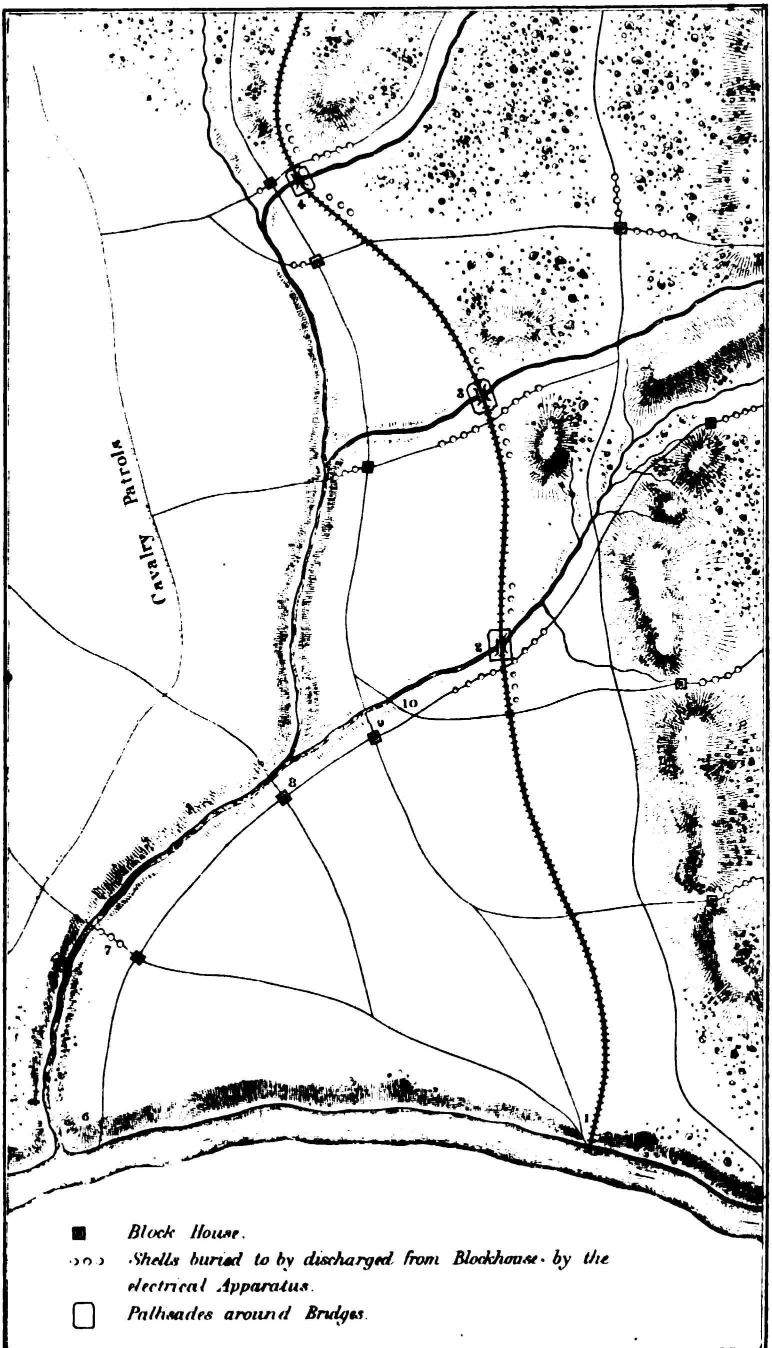

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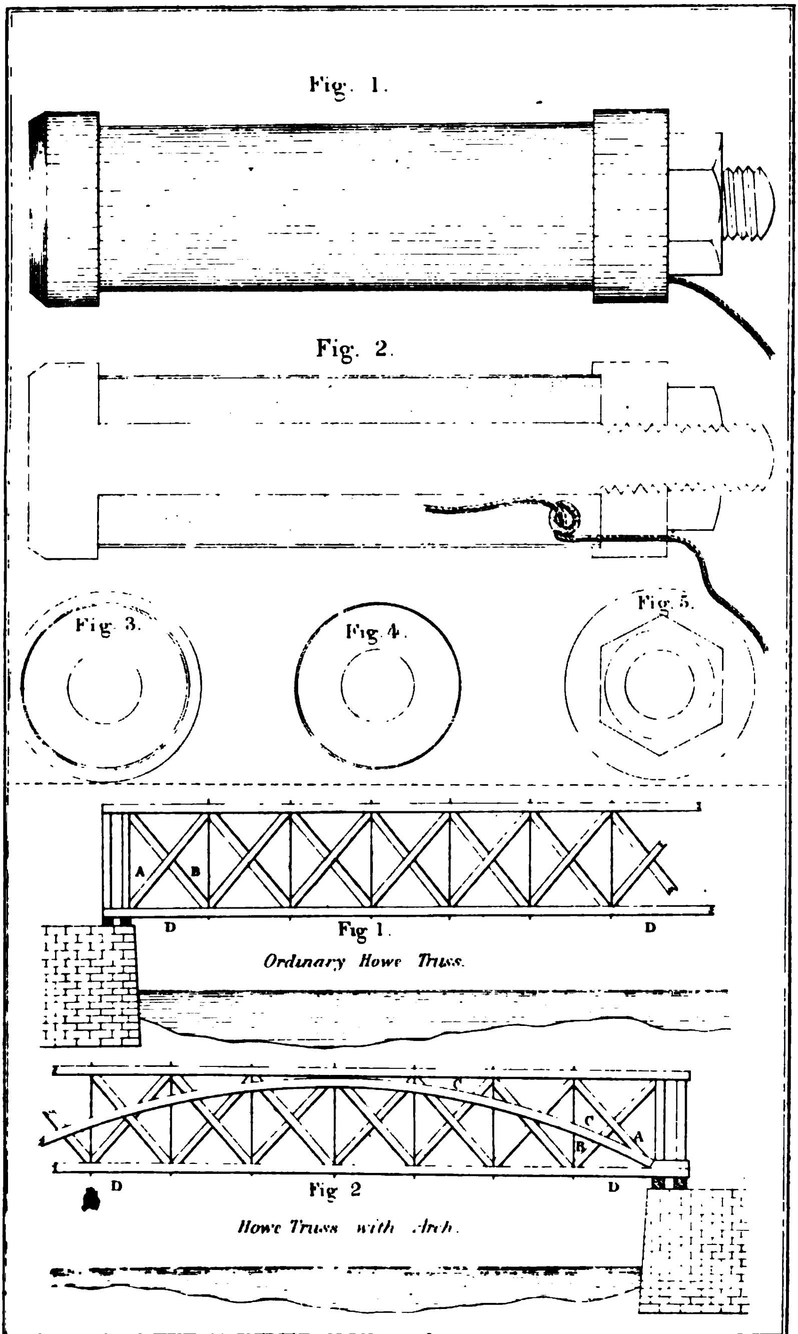

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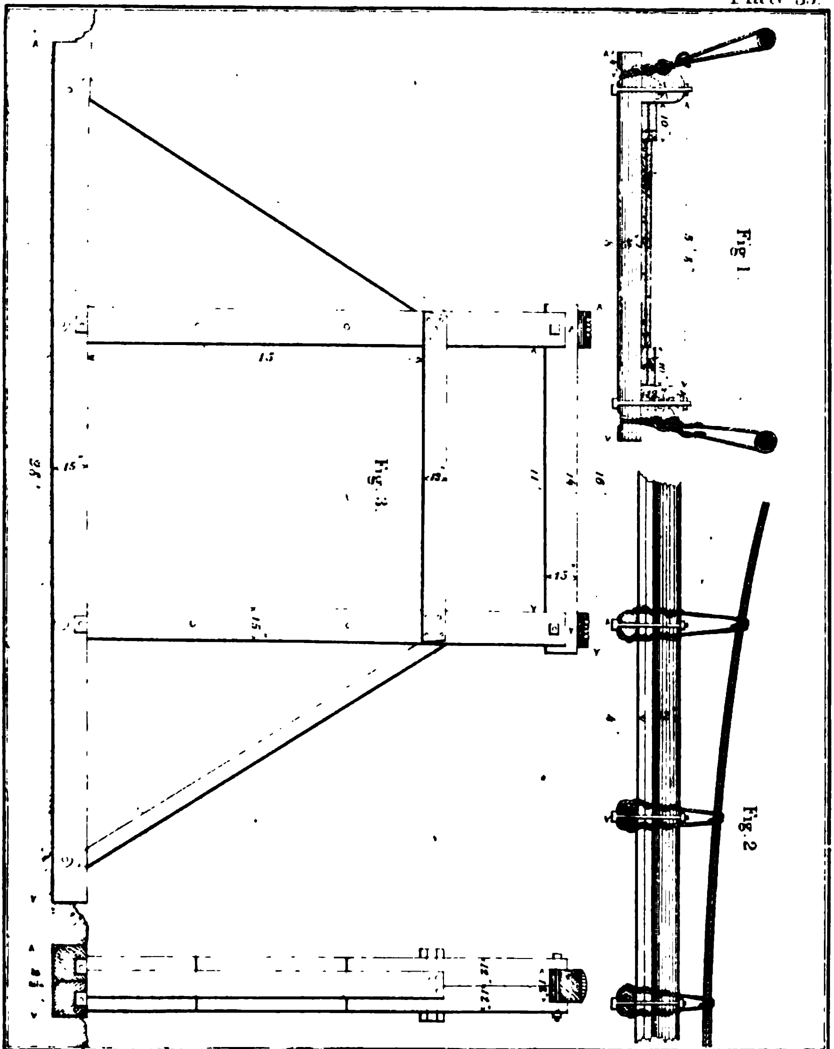

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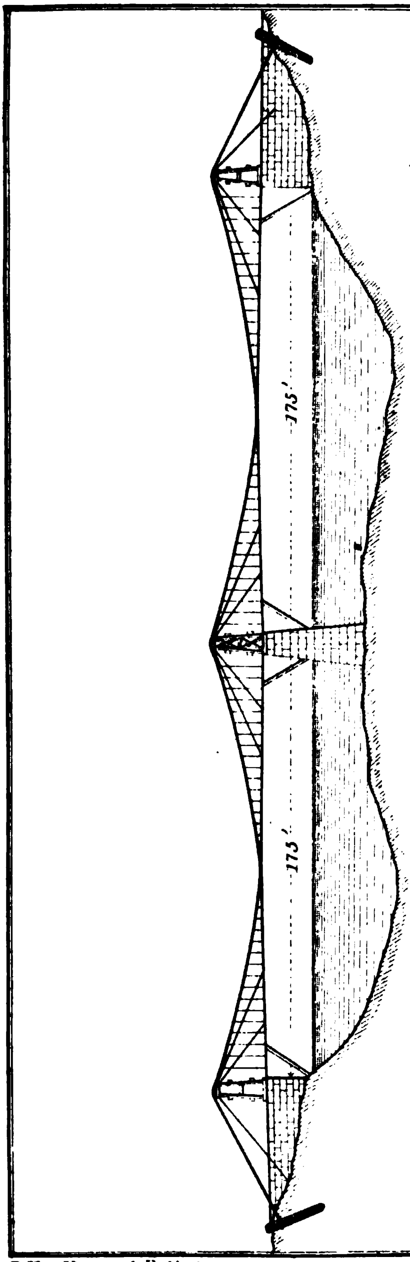

In this case the Old Bridge has been burnt down, leaving the centre Pier and the abutment walls standing. The same size of rope will be used as for a 200 ft. Span.

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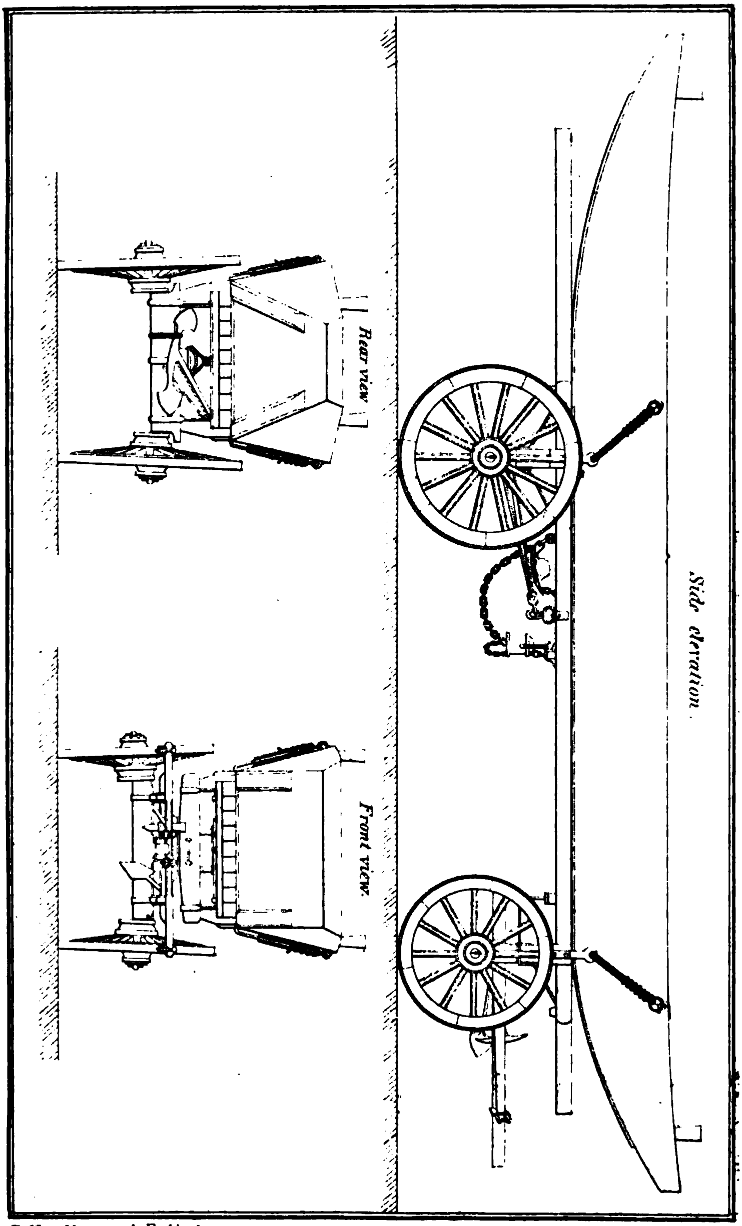

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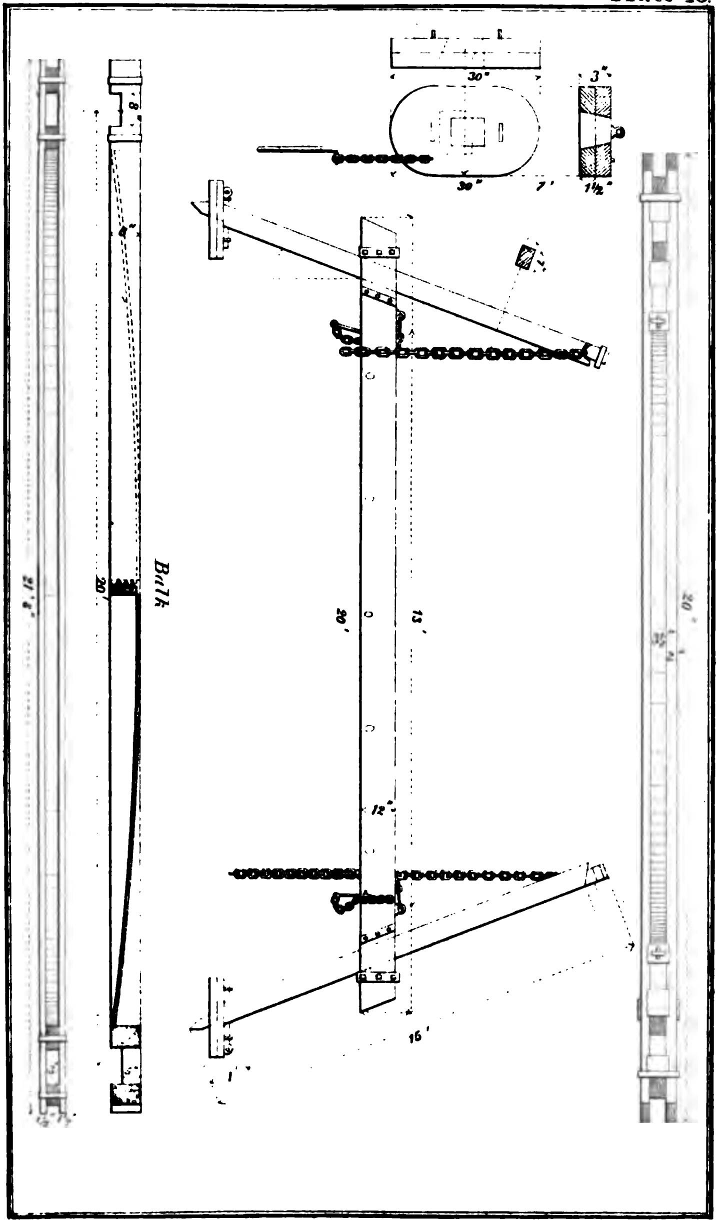

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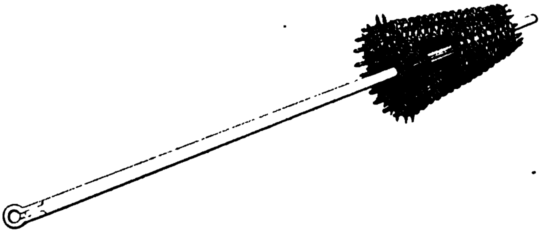
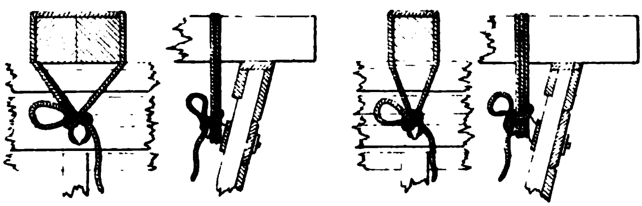
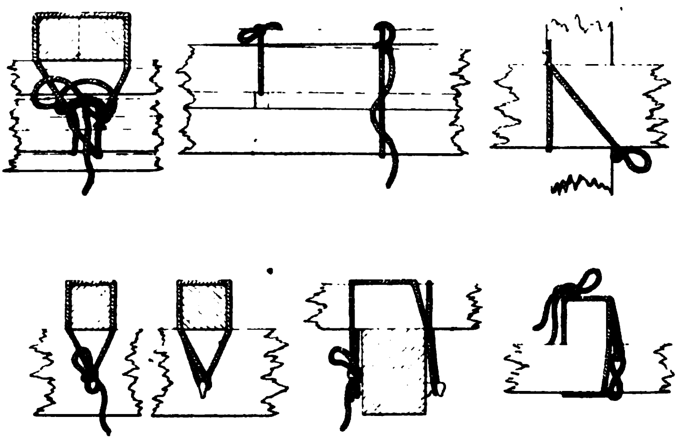
Anchoring pannier



Balk lashing



Rack lashing



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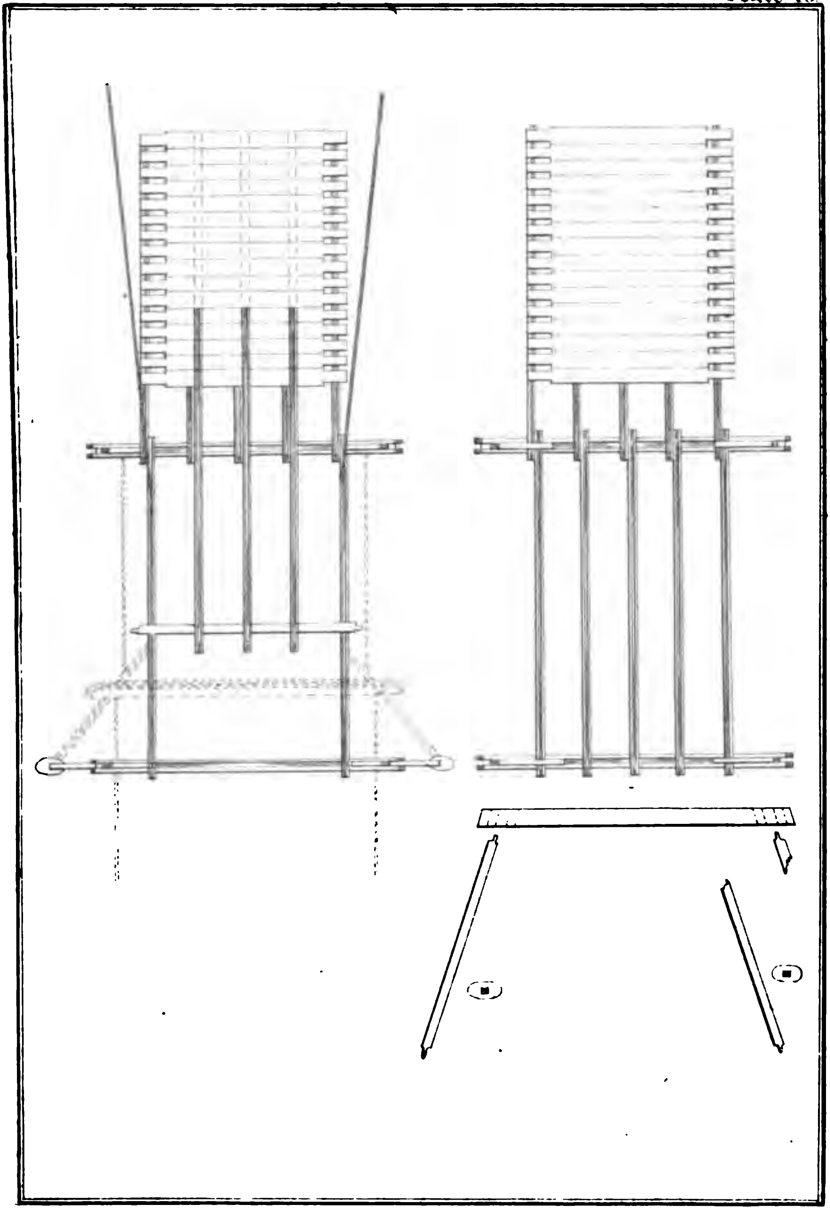

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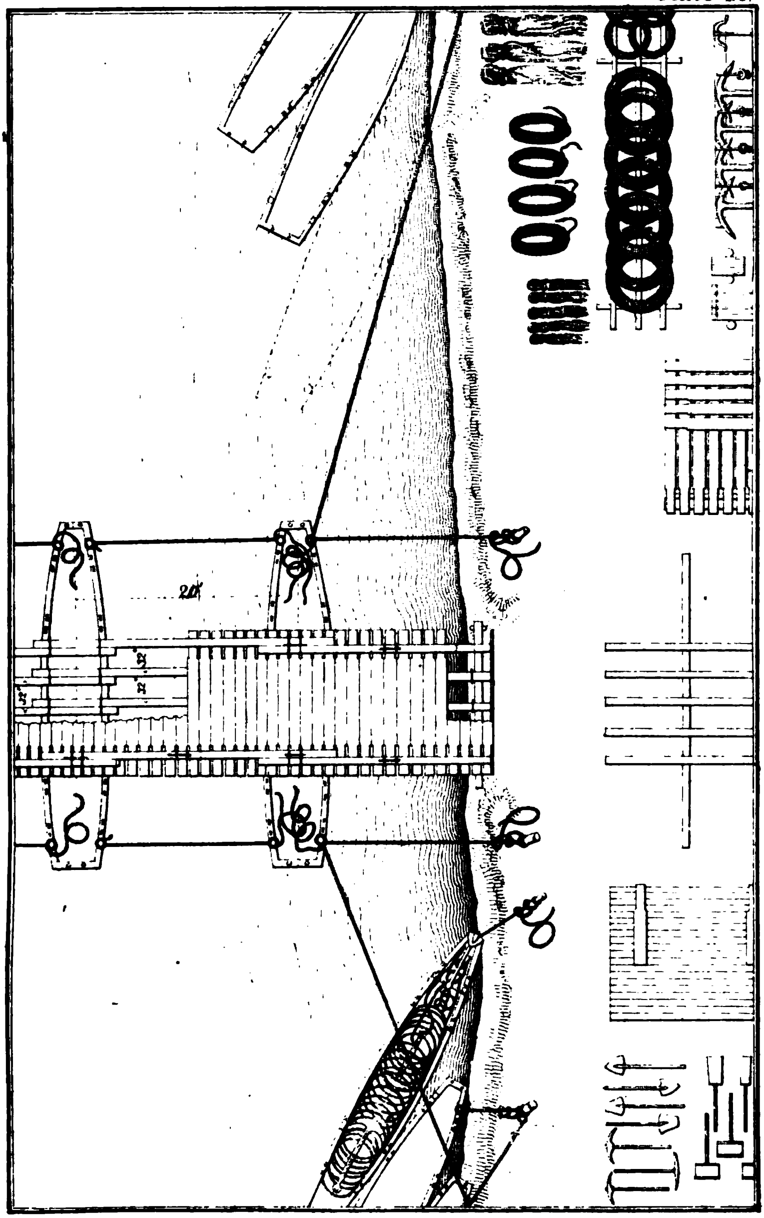

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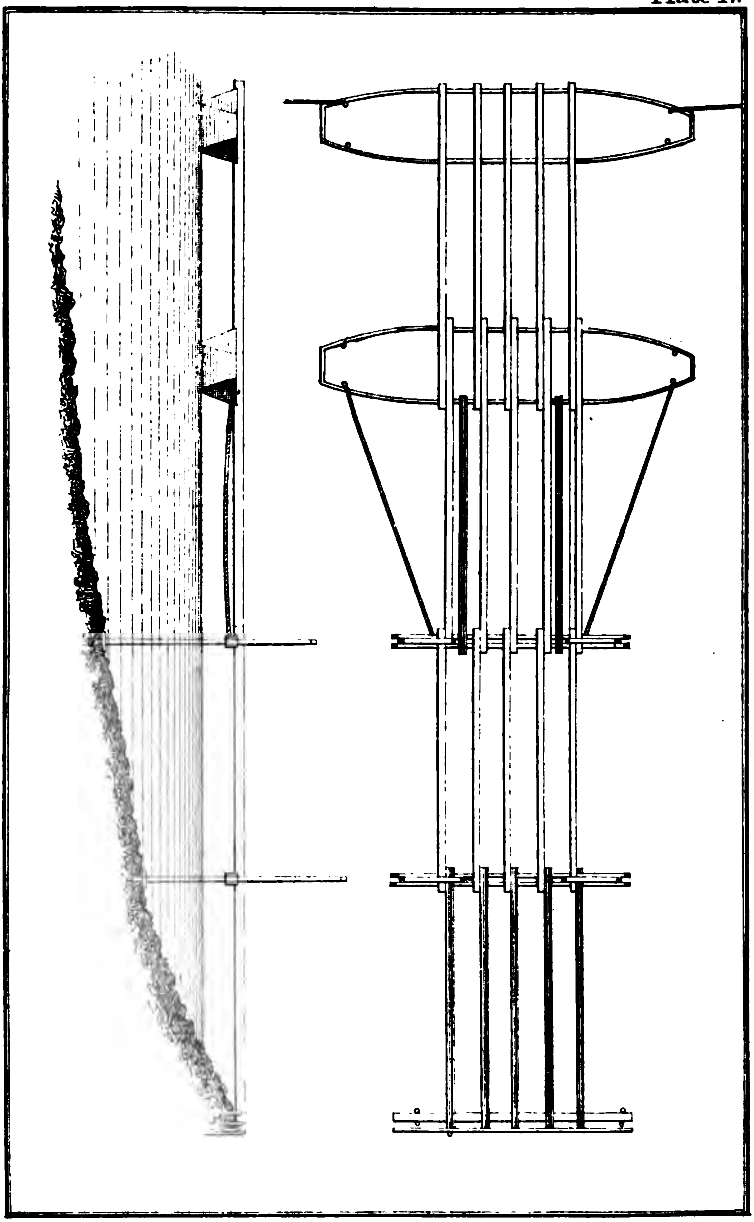

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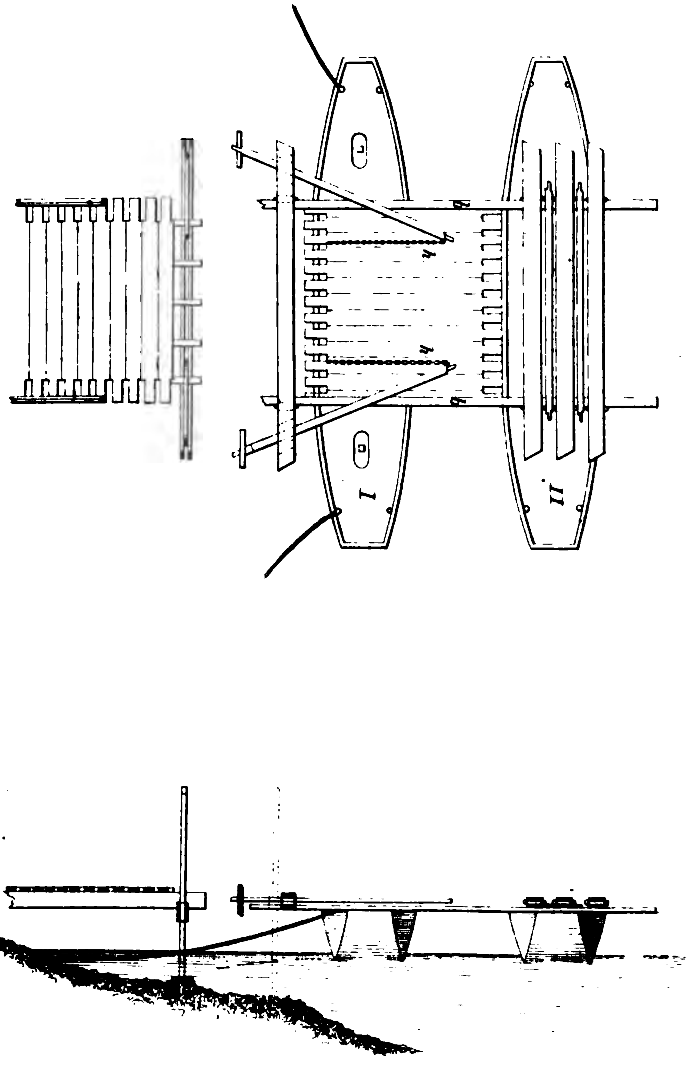

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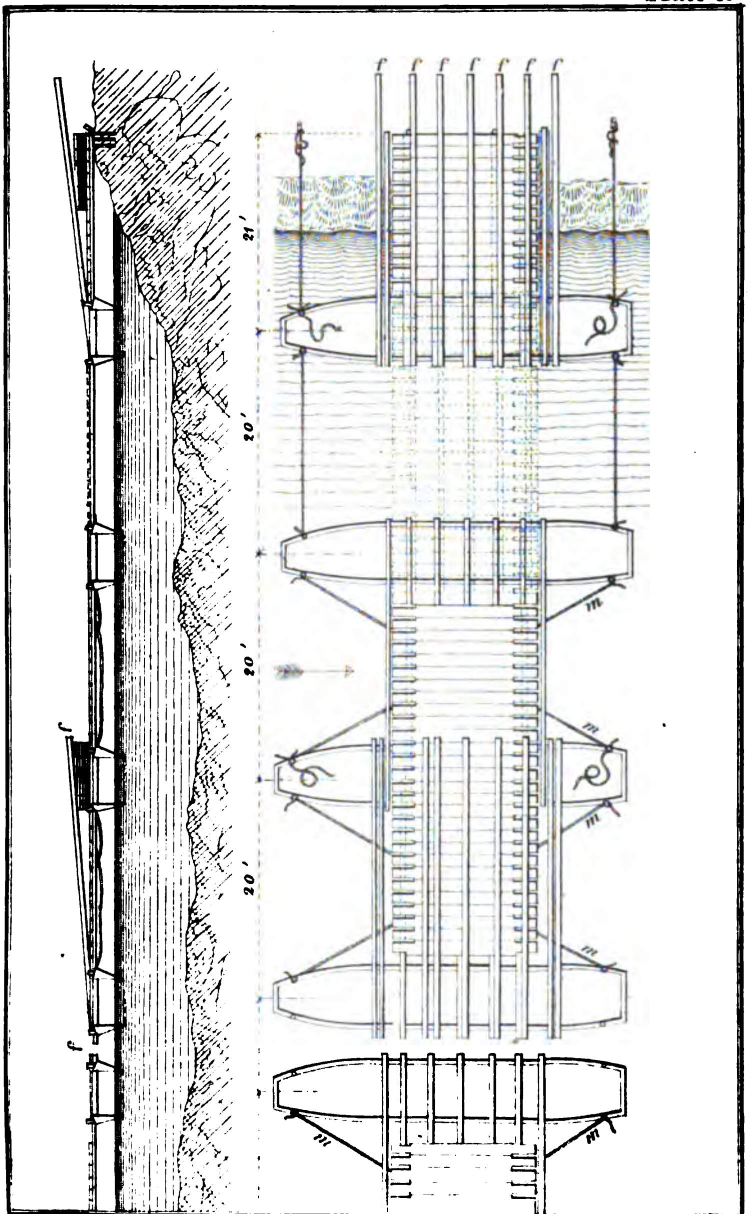

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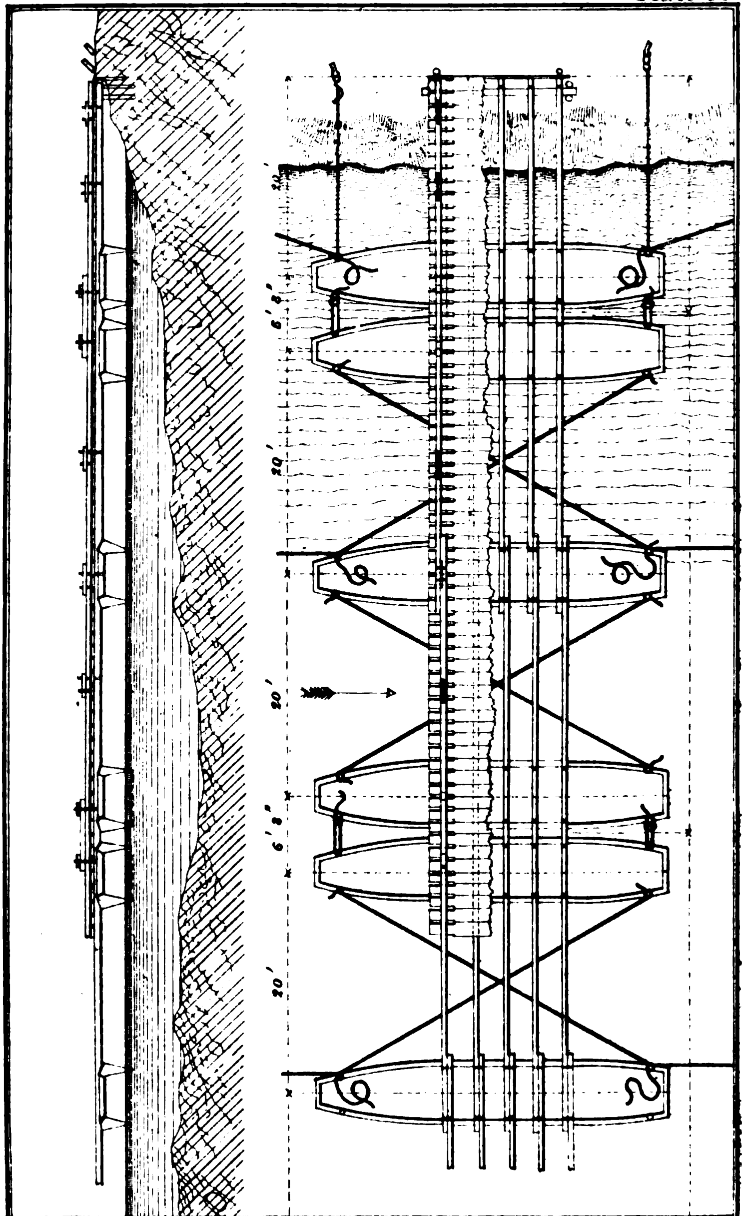

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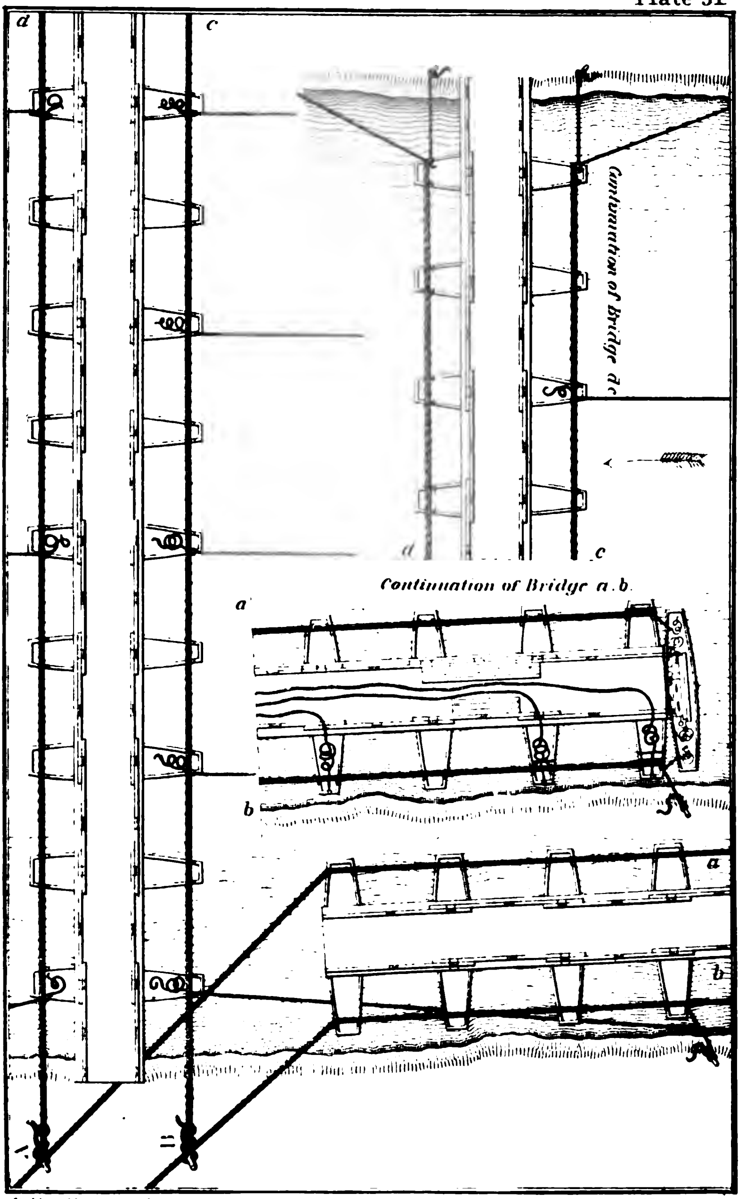

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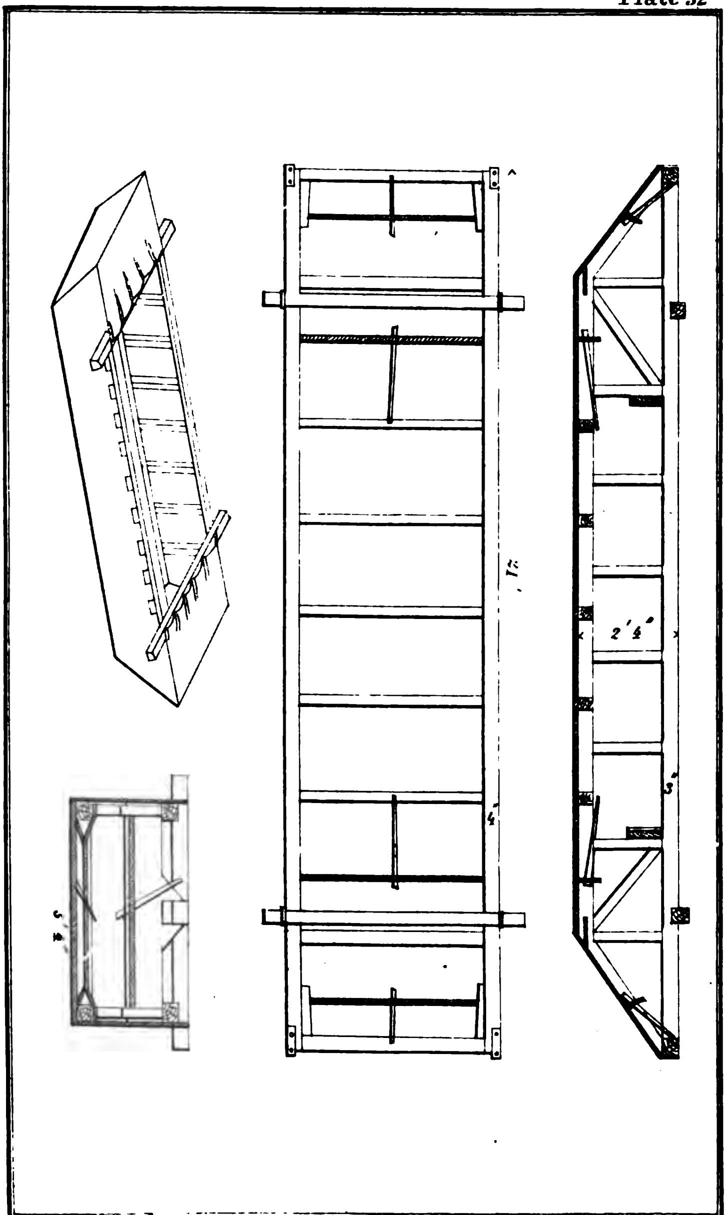

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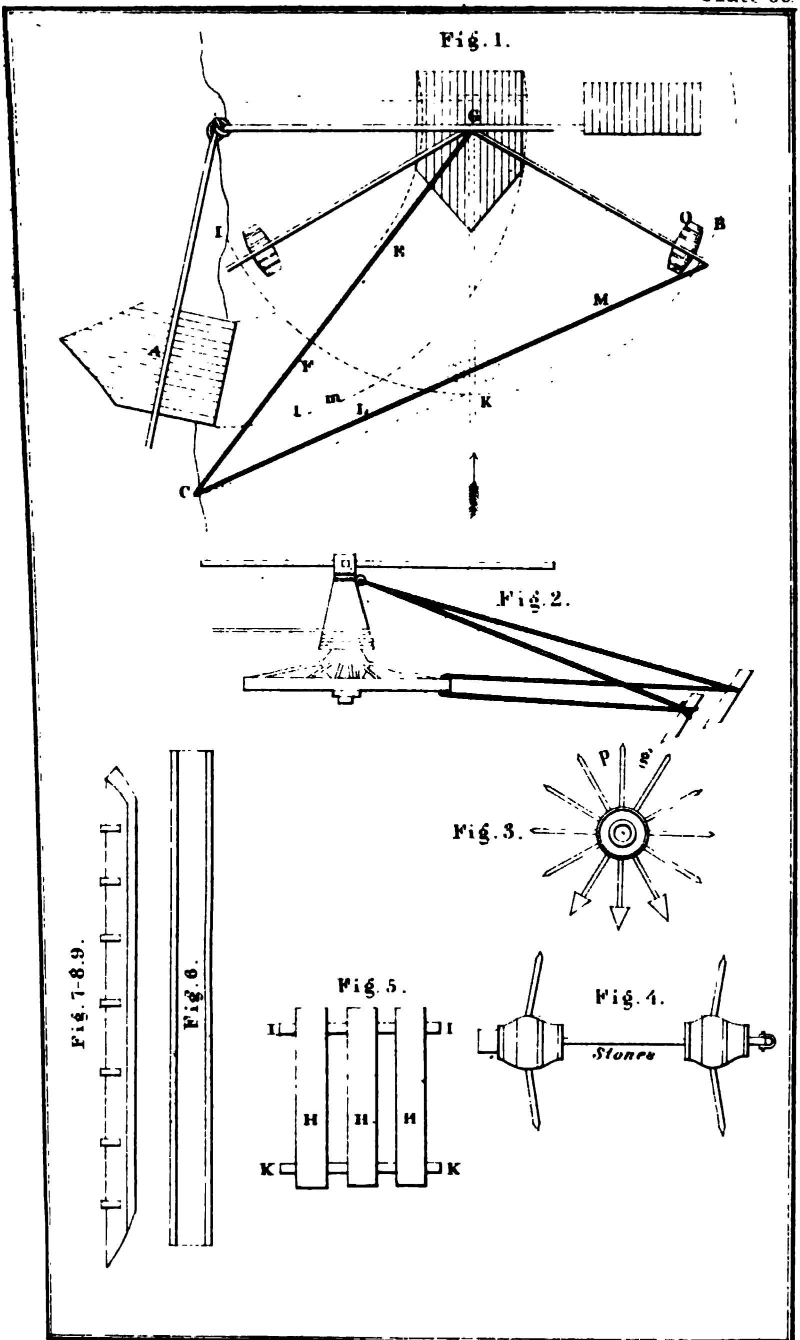

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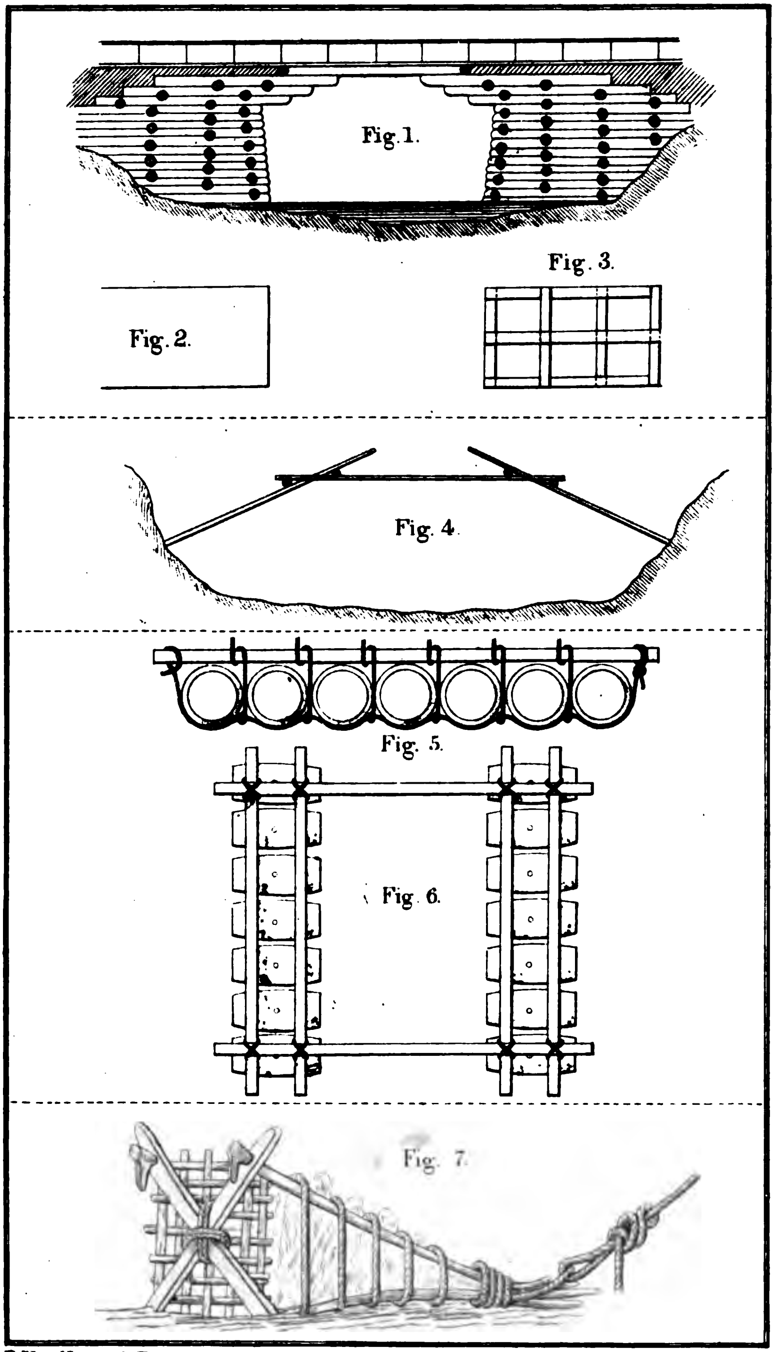

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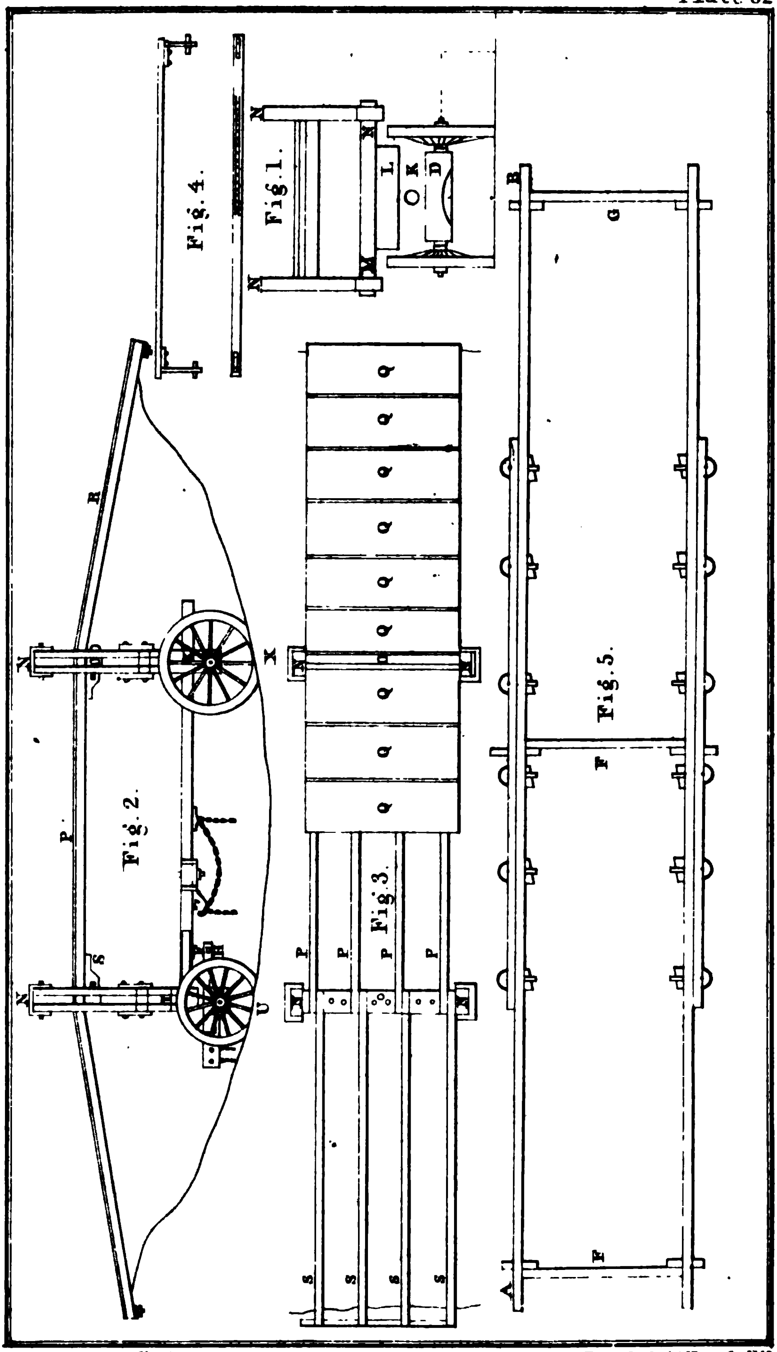

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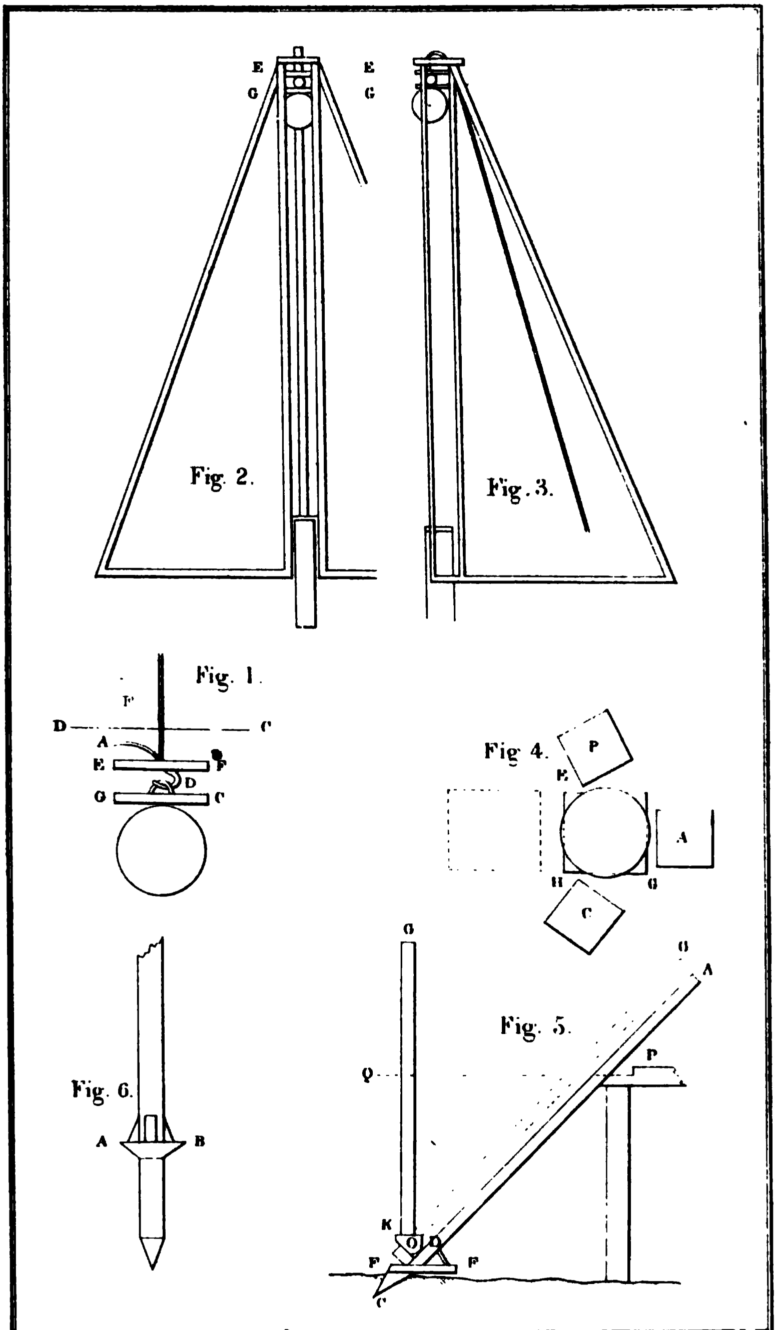

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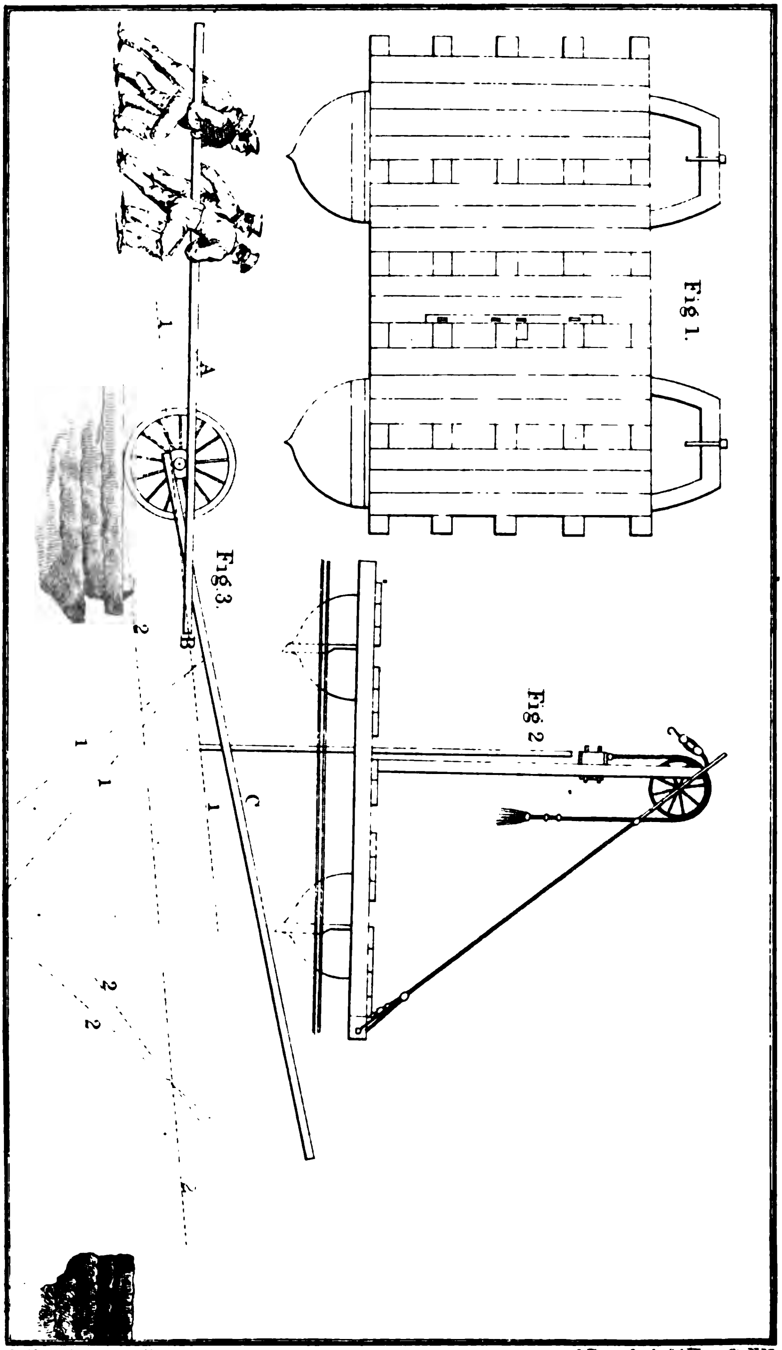

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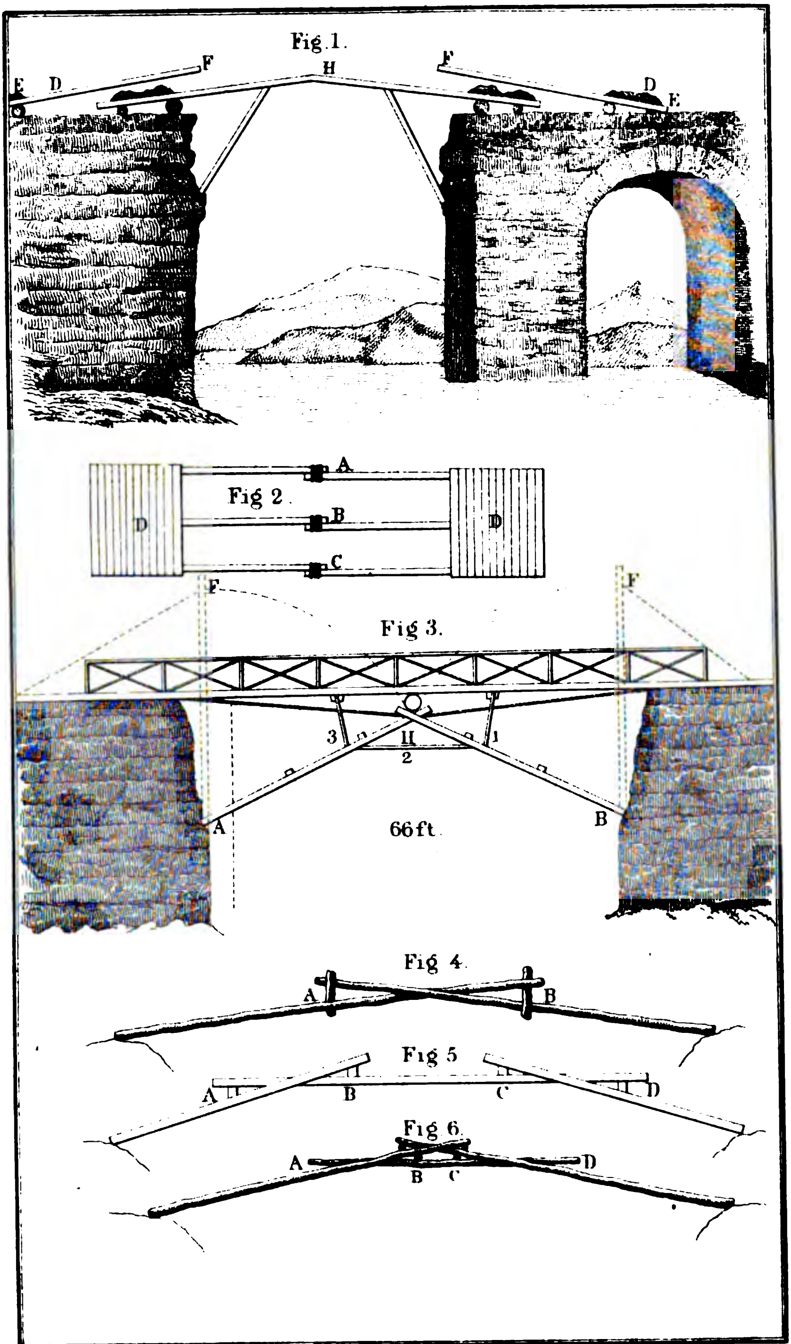

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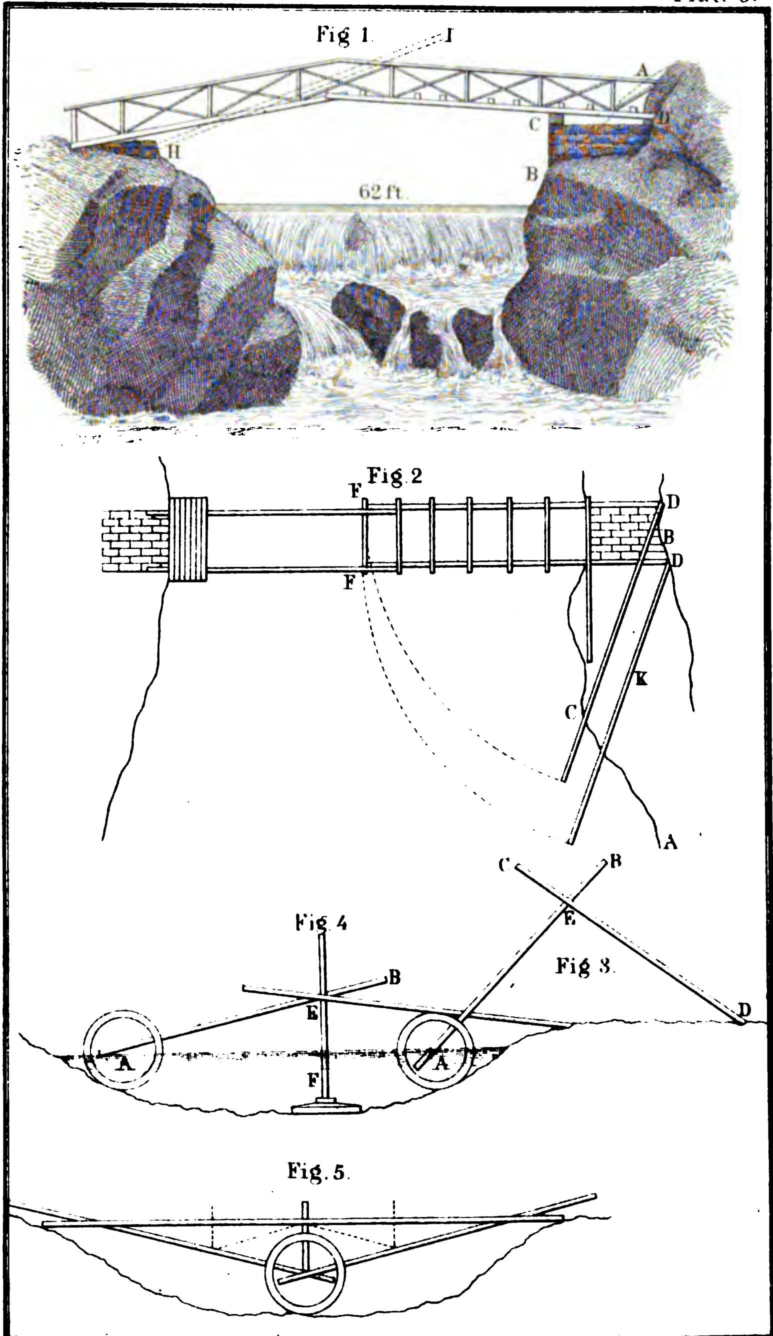

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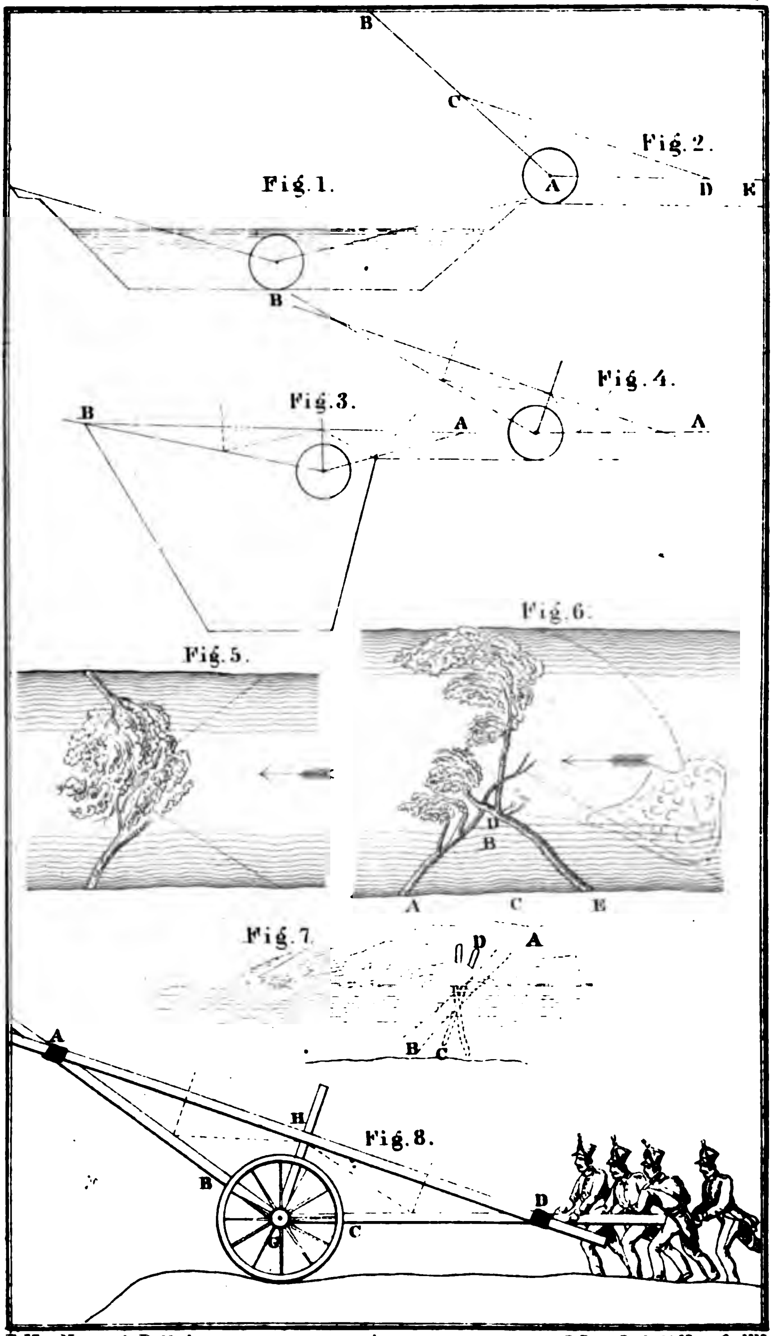

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